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Technologie

THE

TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOLUME XII.

BOSTON:
MASSACHUSETTS INSTITUTE OF TECHNOLOGY.
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The objects of the Society are to awaken and maintain an active interest in the sciences and their practical applications, and to aid generally in their advancement in connection with the arts, agriculture, manufactures, and commerce. Regular meetings are held semi-monthly from October to May.

The Society discontinued the publication of the *Abstracts of Proceedings* in 1891, and since then has published its proceedings and the principal papers read at its meetings in the *Technology Quarterly*. The present volume contains the proceedings from October, 1898, to May, 1899, inclusive.

The *Quarterly* contains, also, the results of scientific investigations carried on at the Institute, and other papers of interest to its graduates and friends.

Neither the Massachusetts Institute of Technology nor the SOCIETY OF ARTS assumes any responsibility for the opinions or statements in the papers.

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Objects of the Society.

The objects of the Society are to awaken and maintain an active interest in the practical sciences, and to aid generally in their advancement and development in connection with arts, agriculture, manufactures, and commerce.

The Society invites all who have any valuable knowledge of this kind which they are willing to contribute to attend its meetings and become members. Persons having valuable inventions or discoveries which they wish to explain will find a suitable occasion in the Society meetings, subject to regulations hereafter provided; and while the Society will never indorse, by vote or diploma or other official recognition, any invention, discovery, theory, or machine, it will give every facility to those who wish to discuss the principles and intentions of their own machines or inventions, and will endeavor at its meetings, or through properly constituted committees, to show how far any communications made to it are likely to prove of real service to the community.

Section I. — Administration.

The immediate management and control of the affairs of the Society of Arts shall be exercised by an Executive Committee, consisting of the President of the Institute and the Secretary of the Society (who shall be members *ex officiis*), and five other members, who shall be elected by the Society of Arts at each annual meeting, to continue in office until other persons have been chosen in their place.

Sect. II. — Duties of the Executive Committee.

The Executive Committee shall elect its chairman, prescribe his duties, and, with the concurrence of the Treasurer of the Institute, fix his compensation when the interests of the Society require that

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printed below) and presented in writing at a preceding meeting of the Society.

2. These By-Laws shall take effect immediately after their approval by the Corporation and adoption by the Society, and all previous By-Laws are hereby repealed.

As amended December 9, 1897.

EXTRACT FROM THE BY-LAWS OF THE CORPORATION.

SECT. VI. — There shall be a Committee on the Society of Arts consisting of five members, appointed at the annual meeting of the Corporation, to hold office for one year, who shall have the general charge and supervision of the organization and proceedings of the Society, subject to the approval of the Corporation. It shall be their duty, in connection with a committee chosen by the Society, to frame By-Laws for the government of the Society, which shall take effect when adopted by the Society and approved by the Corporation.

February, 1894.

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DECEMBER, 1899.

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TECHNOLOGY QUARTERLY·

AND·PROCEEDINGS·OF·THE·

SOCIETY OF ARTS

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PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. XII. MARCH, 1899. No. 1

PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTY-SEVENTH YEAR, 1898–99.

BOSTON, October 13, 1898.

THE 514th regular meeting of the SOCIETY OF ARTS was held at the Institute on this day at 8 P.M., with Professor W. T. Sedgwick in the chair, thirty persons present.

The record of the previous meeting was read and approved. The following papers were presented by title:

"Producing Illuminating Gas and Coke in By-Product Ovens," by H. O. Hofman.

"A Modification of Bischof's Method for Determining the Fusibility of Clays, as Applied to Non-Refractory Clays, and the Resistance of Fire Clays to Fluxes," by H. O. Hofman.

"Does the Size of Particles Have any Influence in Determining the Resistance of Fire Clays to Heat and to Fluxes?" by H. O. Hofman and B. Stoughton.

The Chairman then introduced Mr. Simeon C. Keith, Jr., of Boston, who read a paper on "Bacteria in Milk, including their Rôle in Butter and Cheese Making."

Mr. Keith gave a general description of bacteria, and especially those in milk, with their functions in the ripening of cream. He

described briefly the various methods of separating milk and cream, especially that of the centrifugal machine, explained the use of special cultures of bacteria in butter and cheese making, and compared the value of various kinds. Then followed a description of some dairies visited, with a statement of what might properly be expected from them.

A discussion followed, after which the Chairman thanked Mr. Keith for his interesting paper, and the Society then adjourned.

BOSTON, October 27, 1898.

The 515th regular meeting of the SOCIETY OF ARTS was held at the Institute on this day at 8 P.M., with Professor Peabody in the chair, twenty-five persons present. The record of the previous meeting was read and approved.

Mr. P. B. Wesson, of Lowell, and Mr. William L. Draper, of Boston, were elected Associate Members of the Society.

The Chairman then introduced Mr. Henry G. Kittredge, of Boston, who read a paper on "Wool; with Practical Features that Enter into the Forming of a Wool Tariff. A Description of the Processes of Manufacture," with stereopticon illustrations.

He explained the essential differences between angora, alpaca, and merino sheep, showing that the classification is based on the differences in species. The operations of shearing, washing, scouring, sorting, etc., were described, and the careful methods in vogue in Australia dwelt upon to some extent. The different grades of wool from the same fleece were illustrated, and the processes of manufacture described.

A discussion followed, after which a vote of thanks was given to Mr. Kittredge for his excellent paper, and the meeting then adjourned.

BOSTON, November 10, 1898.

The 516th regular meeting of the SOCIETY OF ARTS was held at the Institute on this day at 8 P.M., with President Crafts in the chair, eighty-eight persons present. The record of the previous meeting was read and approved.

The Chairman then introduced Mr. Frederic P. Stearns, Chief Engineer of the Metropolitan Water Board, who read a paper on the "Metropolitan Water Supply," illustrated by stereopticon views.

Mr. Stearns gave a luminous account of the work done by the board, and of the many difficulties which had vanished as the work progressed. The problem consisted of two phases: to collect good water and send it to the Sudbury system of reservoirs, and to distribute it to the cities and towns within the ten-mile limit.

The completion of the tunnel and aqueduct to Basin 5 left the dam at Clinton, and the stripping and cleaning of the Wachusett Reservoir, as simple though immense operations to be performed. The distribution problem is now partially solved by the construction of two 48-inch pipe lines from Chestnut Hill to Spot Pond in Malden. The completion of the high service reservoir in the Fells will finish the work for the northern district.

The natural topography at both Clinton and Malden is so fortunate that the board is saved many millions of dollars by taking advantage of it. As a result, the water will cost very much less per million gallons than that of the large Croton Reservoir of New York, and even much less than the water from the economically constructed reservoir of the Sudbury and Cochituate systems. A discussion followed, after which the Chairman thanked Mr. Stearns for his very interesting paper, and the meeting then adjourned.

BOSTON, December 8, 1898.

The 517th regular meeting of the SOCIETY OF ARTS was held at the Institute on this day at 8 P.M., with President Crafts in the chair, seventy-two persons present. The record of the previous meeting was read and approved.

Mr. Henry B. Dates, of Potsdam, New York, Professor of Electrical Engineering in the Clarkson School of Technology, and Dr. Frederic S. Hollis, of Newton Highlands, were elected Associate Members of the Society.

The Chairman then introduced Professor W. O. Crosby, of the Massachusetts Institute of Technology, who read a paper, illustrated by lantern views, on the "Geology of the Wachusett Reservoir."

He gave a description of the geological features of the Nashua Valley, and of the strata encountered in the tunnel. The leading feature in its geological history was the influence of the glacial epoch. Large deposits of sand were laid down, and the action of the ice in the glacial lake, at that time occupying the larger portion of the valley, was to form the series of kettle holes, some of which contain small and even large ponds, which are so prominent a feature of the valley. The cut made for the discharge of the water in Sandy Pond led to the discovery of buried kettle holes where the ice boulder had been buried under one or more sand layers before melting.

The feature of leading importance to the engineer was the great difference between the two sides or walls of the valley. The southern side is steep and angular, with hard rocks, diorites, and quartzites predominating, while the northern and western sides are shelving and sloping, and composed of soft and cleaving rocks, such as mica schist. A great many borings were made on the sites of the great dam, and of the earthen dikes, and the facts thus ascertained were of the greatest importance in planning for the construction of the works.

A discussion followed, after which the meeting adjourned.

BOSTON, December 22, 1898.

The 518th regular meeting of the SOCIETY OF ARTS was held at the Institute on this day at 8 P.M., with President Crafts in the chair, three hundred persons present.

The Society met with invited guests for the purpose of opening the Pierce Building to the interested public. Addresses were made by the President, Professor Homer, Professor Woodbridge, Professor Puffer, Professor Sedgwick, and Professor Lanza, explaining the design and construction of the building, and the various problems met.

The guests and members then visited the various departments in the building, also the engineering laboratories. Refreshments were served in the lunch room.

ARTHUR T. HOPKINS, *Secretary.*

REPEATED STRESSES.

By JEROME SONDERICKER.

Read January 12, 1899.

REPEATED stresses are of common occurrence in engineering structures. The moving parts of machines are, as a rule, subjected to such stresses. A piston rod, for example, changes from tension to compression at each stroke, and this is accompanied by bending if the alignment is imperfect. Connecting rods and parallel rods are subjected to alternate tension and conpression, accompanied by bending back and forth. The stress in the fibers of a shaft rotated under a transverse load, changes from tension to compression and back at each revolution. Propeller shafts, crank shafts, and car axles are under similar treatment. Ordinary wagon axles are repeatedly bent in one direction due to the roughness of the ground. A rail is bent each time a car wheel passes over it. A band saw is bent and unbent as it passes on and off the pulley. The parts of a bridge are subjected to repeated stresses as the loads pass on and off. There are varying stresses due to the action of wind and wave, also to changes of temperature, etc.

Breakages in such cases as I have mentioned are, more or less frequently the result of these repeated stresses. It is evident that a thorough acquaintance with the conditions which lead to such breakages is of great importance to the engineer.

When wrought iron or structural steel is tested in an ordinary testing machine, by pulling apart in tension, by bending, crushing, etc., the piece is broken by a load gradually applied once. The material being ductile, is considerably distorted before fracture takes place, the circumstances leading to fracture being those which accompany the flow of a plastic mass. The circumstances accompanying fracture under repeated stresses are entirely different, so that the strength of a piece under such stresses cannot be learned from the results of an ordinary test. Although Wöhler began his repeated stress tests nearly forty years ago, much still remains unknown respecting the effect of such stresses. Moreover, the information already gained seems not to have reached the notice of many engineers, if we may

judge from statements appearing frequently in the engineering periodicals.

The tests to be presented in this paper were made on rotating shafts, subjected to a transverse load, the stress, therefore, varied during each revolution between tension and compression of equal intensity. The specimens tested included wrought iron and structural steel, the steel varying in carbon from .08 or less, to .50 per cent., and in tensile strength from about 45,000 pounds to about 100,000 pounds per square inch. The speed of rotation varied from about 350 to 500 revolutions per minute. With the exception of a few cold rolled pieces, the metal was tested in the condition in which it came from the mills. The testing machine has been described in a previous paper. (See *Technology Quarterly*, April, 1892.)

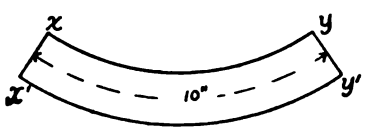


Fig. 1.

The sets recorded in the tables need explanation. The measurements are taken between two arms clamped to the shaft 10 inches apart (Figure 3.) As the shaft revolves each fiber is alternately stretched and compressed. If the shaft be stopped with a given fiber on the compression side and then unloaded, the shaft, because of the set, will retain a slight curvature, with the fiber in question on the concave side, as $x\,y$ (Figure 1). If, on the other hand, the shaft were stopped 180° from its former position and then unloaded, the same fiber would be on the convex side, as $x'\,y'$. The difference in length of $x'\,y'$ and $x\,y$ is the set recorded. It is somewhat less than would be the case if the piece were subjected to direct tension and compression stresses, because the interior fibers, being under less stress, tend to straighten the shaft when it is unloaded.

Our present object is to give a general discussion of the results obtained up to date. These include, in addition to the writer's tests, three theses by graduates of the Massachusetts Institute of Technology, namely: Stephen Bowen, class of 1892, E. B. Carney, 1893, and M. E. Taylor, 1898.

The investigations were conducted along two lines. 1. The determination of the elastic changes resulting from the repeated stresses, and the influence of such changes in causing fracture. 2. The influence of form, flaws, and local conditions generally in causing fracture. These will be discussed in turn.

I. Elastic Changes Produced by Repeated Bending Stresses.

The planning of the tests was based on the consideration that structural or other changes in the metal would probably be accompanied by elastic changes. A careful study of the elastic changes occurring was, therefore, made. The details of the method followed are explained in my first paper. It is sufficient here to say that accurate measurements of the elastic strains and set were made at intervals during each test. Some of the bars broke without any such changes occurring. In the majority of cases, however, such changes did occur.

1. *Characteristic Curves of Set.* — Figure 2 indicates the general character of the changes which occurred in the set, the abscissae being the number of revolutions, and ordinates the amount of the set. *a* is the characteristic curve for wrought iron, and also occurred in one kind of soft steel. No change is produced until the elastic limit is reached, and then the change consists in a decrease of set, comparatively rapid at first but finally ceasing, unless fracture intervenes. In some of the wrought iron specimens this gradual decrease was preceded by an initial increase of set. *b* is the characteristic curve for all the steels tested, with the single exception mentioned. It is the reverse of the preceding, beginning commonly below the elastic limit and consisting of an increase of set, rapid at first but finally ceasing. Under heavy loads the increase of set is very rapid and ceases comparatively quickly. Accompanying the change of set there is a change in the elastic strain in the same direction but much smaller in amount. From the fact that these changes finally cease, we conclude that if of sufficiently small magnitude, they do not necessarily result in fracture. From the opposite character of the curves, it would seem that they indicate different kinds of internal change, or are the resultant of at least two kinds of change, one or the other predominating.

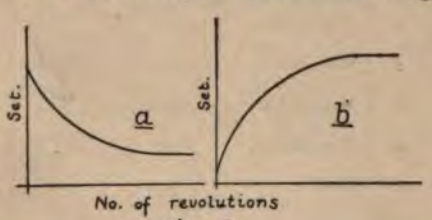


Fig. 2

2. *Stress at which Elastic Change was First Observed, Compared with Elastic Limit and Tensile Strength of the Material.* — Table I contains the results bearing on this point. The 3d column gives the

stress at which elastic change was first observed. In several cases it is evident from the magnitude of the set that changes would have been detected under smaller stresses had the observations been taken. The numbers in the 4th and 5th columns indicate the relative magni-

TABLE I.

Mark.	Material.	Stress at which change was first observed. (Lbs. per sq. in.)	Set.		Revolutions in which change occurred.	Original.		Per cent. of tensile strength.
			Original. (Inches.)	Final. (Inches.)		Elastic limit. (Lbs. per sq. in.)	Tensile strength. (Lbs. per sq. in.)	
D	Wrought iron.	30,000	<.01200	.00165	42,300	15,700	43,080	...
40	Wrought iron.	24,000	.00020	.00016	1,500,000	24,000	50,700	47.
1	Wrought iron.	26,000	.00018 .00026	.00018	2,214,000	25,900	51,390	50.
2	Wrought iron.	32,000	.00069 .00136	.00090	486,000	25,900	51,390	...
3	Wrought iron.	24,000	.00027 .00037	.00012	6,593,000	23,400	50,510	47.
4	Wrought iron.	28,000	.00021 .00042	.00032	2,506,000	23,400	50,510	...
33	Steel.	32,000	.00192	.00740	85,900	24,800	47,400	...
34	Steel.	32,000	.00202	.00832	103,500	24,800	47,400	...
21	Steel.	32,000	.00029	.00012	4,395,000	30,400	62,590	51.
54	Steel.	45,000	.00089	.00310	163,000	42,000	63,130	...
50	Steel.	30,000	.00036	.00100	339,000	23,200	73,760	41.
25	Steel.	40,000	.00016	.00028	5,031,000	38,300	78,010	51.
26	Steel.	40,000	.00017	.00025	20,838,000	38,300	78,010	...
18	Steel.	36,000	.00022	.00052	6,463,000	50,000	81,010	...
19	Steel.	36,000	.00008	.00069	7,252,000	50,000	81,010	...
20	Steel.	34,000	.00007	.00028	21,221,000	50,000	81,010	42.
53	Steel.	50,000	.00012	.00249	24,000	58,000	96,580	...
58	Steel.	45,000	.00003	.00020	50,100	58,000	96,580	47.
29	Steel.	40,000	.00007	.00046	5,257,000	54,000	104,480	38.
55	Steel.	55,000	.00018	.00060	276,900	50,000	104,830	33.
57	Steel.	60,000	.00208	.00768	14,300	50,000	104,830	...

tude of the set when the stress was first applied, *i. e.*, after a few revolutions, and after the number of revolutions given in column 6. The 7th and 8th columns give the elastic limit and tensile strength obtained from the usual tension test. In the wrought iron bars there was an initial increase of set as indicated in the 4th column. A perusal of

TABLE II.

Mark.	Material.	Stress.	Revolutions.	Maximum observed stress.	Remarks.
D	Wrought iron.	30,000	86,400	<.01200	Broke at one end, at shoulder, and at other end where arm was attached.
40	Wrought iron.	24,000	1,500,000	.....	
		26,000	2,427,000	.....	Broke.
1	Wrought iron.	26,000	2,285,000	.00026	Broke near center.
2	Wrought iron.	32,000	486,000	.00136	Broke at mark burned by electric current.
3	Wrought iron.	24,000	6,593,000	.00037	
		24,000	4,059,000	.00011	After resting unloaded 9 days.
		25,000	8,962,000	.00016	
		26,000	3,932,000	.00028	
		27,000	8,155,000	.00037	
		28,000	589,000	.00038	Broke at shoulder.
4	Wrought iron.	28,000	2,506,000	.00042	Broke at center.
33	Steel.	32,000	89,750	.00771	Broke outside of arm near bearing. Color, blue-black.
34	Steel.	32,000	116,600	.00832	Broke outside of arm near bearing. Color, blue-black.
21	Steel.	32,000	4,395,000	.00029	
		34,000	5,339,000	.00032	
		36,000	4,627,000	.00041	
		36,000	1,428,000	.00008	After resting unloaded 18 days.
		38,000	3,769,000	.00023	
		40,000	4,523,000	.00054	
		42,000	505,000	.00072	Broke near shoulder.
54	Steel.	45,000	163,000	.00312	Broke at shoulder.
50	Steel.	30,000	339,000	.00100	
		35,000	16,400	.00282	Not broken.
25	Steel.	40,000	5,031,000	.00028	
		42,000	2,483,000	.00046	Broke at shoulder.
26	Steel.	40,000	20,838,000	.00037	
		42,000	3,311,000	.00044	Not broken.
18	Steel.	36,000	6,982,000	.00052	Broke where arm was attached.
19	Steel.	36,000	7,686,000	.00069	Broke at shoulder.
20	Steel.	34,000	21,221,000	.00028	
		36,000	13,577,000	.00067	
		38,000	2,263,000	.00113	
		38,000	9,237,000	.00116	After resting 6 months, unloaded.
		40,000	932,000	.00177	Broke at shoulder.
53	Steel.	50,000	146,500	.00249	Broke at shoulder.
58	Steel.	45,000	50,100	.00020	
		50,000	156,700	.00289	Broke near middle.
29	Steel.	40,000	5,257,000	.00046	
		42,000	7,125,000	.00067	
		44,000	4,626,000	.00100	
		46,000	6,760,000	.00145	
		48,000	4,965,000	.00196	
		50,000	170,000	.00197	
		50,000	1,080	.00203	After resting unloaded 24 days. Not broken.
55	Steel.	35,000	276,900	.00060	
		40,000	237,900	.00274	
		50,000	22,530	.00615	Broke near shoulder. Color, dark straw.
57	Steel.	60,000	14,900	.00768	Broke near shoulder. Color, dark blue.

this table will show that in case of the wrought iron and one kind of soft steel (No. 21), the effect of the repeated stress was to decrease the set, and that this change apparently first occurred after the elastic limit was passed. (Compare Nos. 40, 1, 3.) In all other cases the set increased, this change apparently beginning below the elastic limit (Compare Nos. 18, 19, 20, 53, 58, 29, 55). That this change should begin below the elastic limit in the second instance and not in the first, would follow from the nature of the change. The last column shows that these changes of set may be expected to begin at stresses varying from $\frac{1}{3}$ to $\frac{1}{2}$ of the tensile strength.

3. *Relation between Elastic Change and Fracture under Repeated Stress.* — Table II gives the number of revolutions under the stresses indicated and the corresponding maximum set observed. From the nature of the case it is impossible to say precisely what connection exists between the amount of set and resistance to fracture. Even with a set of .001″, Nos. 20 and 29 sustained many millions of revolutions. With a set of .002″ and over, the pieces as a rule broke comparatively soon. About all that can be said is that the set does not

TABLE III.

Mark.	Material.	Set.		Maximum after rest.	Time of rest.
		Before rest.	After rest.		
2	Wrought iron.	.00108	.00070	.00092	17 hours.
3	Wrought iron.	.00021	.00017	.00017	5 days.
21	Steel.	.00019	.00008	.00008	5½ months.
54	Steel.	.00142	.00095	.00312	2 days.
50	Steel.	.00089	.00084	.00091	15 hours.
50	Steel.	.00282	.00269	.....	22 hours.
26	Steel.	.00037*	.00015	.00025	11 days.
20	Steel.	.00024*	.00023	.00027	2 days.
20	Steel.	.00113	.00073	.00111	5½ months.
53	Steel.	.00249	.00210	.00412	6 days.
29	Steel.	.00111*	.00119	.00145	1 month.
29	Steel.	.00198*	.00203	.....	24 days.
51	Steel.	.00342	.00322	.00422	2 days.
55	Steel.	.00056	.00052	.00060	15 hours.
55	Steel.	.00275	.00234	.00272	2 days.

* Readings not taken *immediately* before stopping.

appear to have a notable influence in causing fracture until it reaches .001″ or .002″ in a length of 10″.

4. *Effect of Rest on the Set Produced by Repeated Stress.* — Frequently the bars rested over night, and in several cases they were laid aside for some time and then tested again. Some of the more important results are given in Table III. It will be seen that the effect of rest is to decrease the amount of set. In most cases, however, the set lost is soon regained, when the bar is again subjected to the repeated stresses. This is especially noticeable in the case of the harder steels.

5. *Temperature Effects.* — It was noticed throughout the tests, that when running under any considerable set, the shaft was perceptibly warmer in the middle than at the bearings, the temperature increasing with the set. There was no accurate way of measuring this temperature. In four cases, however, the heat was sufficient to color the shafts. No. 55, running under a stress of 50,000 pounds, and a set of about .006″ reached a full straw heat (about 200° C.) before breaking. No. 57 under 60,000 pounds stress, and Nos. 33 and 34 under 32,000 pounds stress reached a blue heat (about 300° C.) before breaking, the set in each case being about .008″ (see Table II). Nos. 33 and 34 were a very soft steel, and Nos. 55 and 57 hard steels. The temperature will, of course, depend upon the relative rate at which the heat is generated and dissipated. If a shorter length of shaft had been under the maximum stress, or if the speed had been less, the temperature reached would have been less, and conversely. In all four cases, the break occurred near the bearings, *i. e.*, where the shaft was coolest. This is in harmony with the fact that steel at a blue heat has a higher tensile strength than at a lower temperature. These results would seem to indicate that these high temperatures are not detrimental to the strength of steel under repeated stresses.

6. *Effect of Repeated Stress and Subsequent Rest upon the Tensile Strength.* — Some of the bars broken by repeated stress, were, after varying periods of rest, tested in tension. The tensile strength and ductility obtained in a few cases are given in Table IV, and compared with the original tensile strength and ductility of the metal. It will be seen that the tensile strength is increased to a marked extent in the soft metals, and slightly in the harder steels. The ductility of all is slightly diminished. These results do not indicate the full extent

TABLE IV.

Mark.	Material.	Original.		Per cent. contraction.	Repeated Stress.		Final.		Per cent. contraction.	Time of rest.
		Elastic limit.	Tensile strength.		Maximum stress.	Maximum set.	Elastic limit.	Tensile strength.		
D	Wrought iron.	15,700	43,080	71.5	30,000	<.01200	.....	51,180	66.7	Some weeks.
33	Steel.	24,800	47,400	67.7	32,000	.00771	33,000	58,500	63.9	2 days.
29	Steel.	54,000	104,480	40.3	50,000	.00203	59,600	106,200	37.3	6 years.
55	Steel.	50,000	104,830	33.0	50,000	.00615	.....	110,100	28.4	7½ months.

of the change as the interior has been under less stress than the surface of the bars. The bars of Table IV had all been subjected to heavy stresses accompanied by considerable set. When the bars are run under stresses causing no elastic changes, as far as is known, no change of elastic properties results from subsequent rest.

7. *Explanation of These Phenomena.* — We wish to know the nature of the internal changes which are indicated by the elastic changes described. While the information at hand is not sufficient to determine this definitely, it suggests possible explanations which will be presented briefly. The reduction in set in the case of wrought iron is similar to that produced by any cold working of the metal, such as stretching, hammering, etc. It seems probable that the effect of the continuous kneading to which the soft iron is subjected in the Repeated Bending Machine, is to stiffen it somewhat. The increase of set observed in steel, both below and above its elastic limit, is probably due to causes which must be sought for in connection with the micro-structure of the metal.

According to Professor Howe, Mr. Sauveur, and others, ordinary unhardened steel may be described as granular in structure, and is made up of two constituents called ferrite and pearlyte. The ferrite is nearly pure iron containing no carbon. Pearlyte is made up of ferrite and a carbide of iron, which latter is so hard as not to be scratched by a needle. The proportion of this carbide increases with the percentage of carbon. Steel is thus non-homogenous, and its different constituents doubtless possess different elastic properties.

Set apparently must indicate either plastic distortion of the par-

ticles or lost motion between them, or both, as change of distance between two nuts on a screw may be due to the screw stretching, or to backlash. The increase of set below as well as above the elastic limit which occurs in steel, may be due to the stress being unequally distributed through the mass. To illustrate, — imagine a bundle of wires, some ductile, others hard and brittle, loaded in tension so that all must stretch equally. When the elastic limit of the ductile wires is passed, they will no longer support their portion of the load, some of it being transferred to the more unyielding wires. The hard wires might be able to withstand one application of this unduly heavy stress, but might fail if such stress were repeated a sufficient number of times. The effect of such failure would be to stretch the ductile wires further.

Similarly, in a non-homogeneous material such as steel, the different portions of its structure are probably unequally stressed. When the elastic limit of the soft portion is reached, the more unyielding parts must be stressed excessively. If under repeated applications of this stress they yield, by fracturing or otherwise, the soft portions will be further distorted until equilibrium is again established, *i. e.*, the set would increase. At the same time the working of the soft iron would stiffen it. Under these combined influences, the increase of set might finally cease, and possibly be succeeded by a decrease. Some such action as that described would account for the behavior of the steels under repeated stresses.

A systematic study of the chemical composition and micro-structure of the steel, made in connection with such tests as have been described, could hardly fail to be of value to both the engineer and metallurgist. In none of these tests was there any noticeable change of structure, crystallization, or anything of the sort. No. 55 had been subjected to repeated stresses of such magnitude as to raise the temperature of the bar to a straw heat, after which it rested $7\frac{1}{2}$ months. If any change of structure were to occur, it would be looked for under such severe conditions. Yet when pulled in tension afterwards, the fracture was not different in appearance from the original. The same is true for No. 33, which had been raised to a blue-black heat by the repeated stresses.

It may be well here to say that, unless one is familiar with the appearance of fractures, erroneous conclusions are liable to be drawn from them. In the same metal, the appearance of the fracture varies

greatly with the way in which it is produced. When ductile iron or steel is pulled apart in tension, the metal is drawn down, the particles are very much disturbed and distorted, the fracture resulting from the flow of the metal. If the same bar be nicked or cracked, and then broken suddenly, there is no opportunity for this flow of metal to occur. The conditions of fracture are similar to those of a brittle material, and the appearance is quite different from the preceding. In a shearing fracture the sliding action produces an appearance sometimes described as silky. Under repeated stresses the piece gradually cracks through, with no more alteration of section than in a cracked piece of crockery.

II. Influence of Form, Flaws, and Local Conditions Generally, in Causing Fracture.

In Figure 3, *B B* are the supports, and *C C* the boxes at which the loads are applied, the portion of the shaft between these latter being under uniform bending moment. The measuring arms were attached by means of split rings, *A A*. These rings indented the shaft slightly. In some cases the shafts were of uniform diameter; in others the middle portion was reduced a trifle in diameter, as shown. As the whole length of shaft between the inner boxes, or between the shoulders when the shaft was turned with shoulders, was subjected to the same stress, the fracture would occur at the weakest section in this length. The influence of local conditions in determining the point at which fracture began could thus be observed.

The fractures in this respect are grouped as follows: 8 broke without any local cause being apparent; 9 broke at or near one of the shoulders; 3 where one of the measuring arms was attached, the ring causing an indentation of about .001″; 2 at slight flaws in the surface of the bar, and 1 at a place where the bar was slightly burnt by the electric current. In two instances the fracture occurred where the stress was less than the maximum. One bar broke at a slight flaw, the stress being 4 per cent. less than the maximum, and the other at a dent .005″ deep, where the stress was 13½ per cent. less than the maximum.

Mr. Carney, in his thesis, made a further investigation into local conditions affecting fracture, as follows:

In steel bar No. 24 a groove about .003″ deep was cut by a diamond pointed tool. The shaft was also indented by three set screws, namely,

by a cup-shaped one and a round-ended one each to a depth of $\frac{1}{64}''$, and by a pointed one to a depth of $\frac{1}{32}''$. Under these conditions the bar withstood 6,000,000 revolutions under a stress of 20,000 pounds, but broke after 2,300,000 revolutions under a stress of 25,000 pounds, the break occurring at the groove. This bar was from the same steel as No. 21, which had sustained 6,000,000 revolutions under 40,000 pounds stress, and broke after 500,000 revolutions under 42,000 pounds stress. The groove had apparently reduced the strength about 40 per cent.

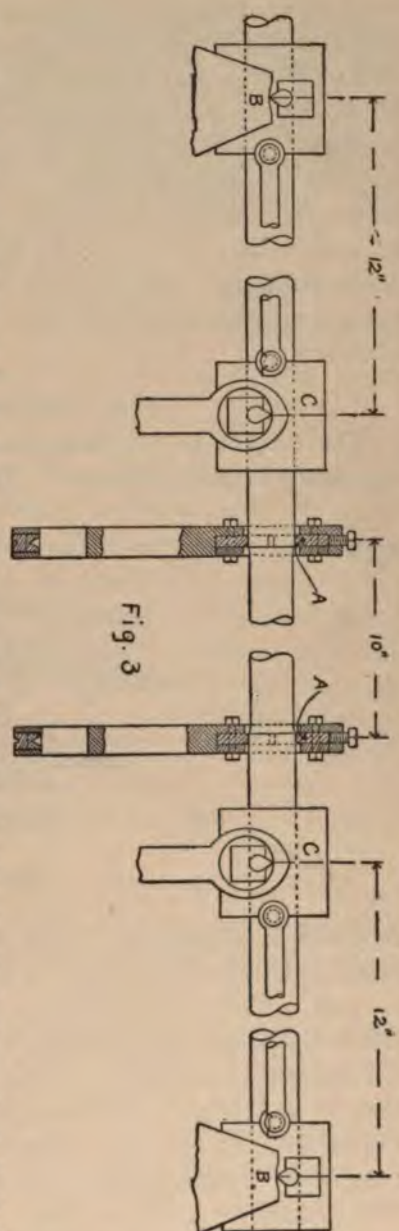


Fig. 3

Steel shaft No. 29 had previously withstood 5,000,000 revolutions under 48,000 pounds stress, and did not break after 200,000 revolutions under 50,000 pounds stress. One inch length of this shaft was then reduced in diameter from 1″ to .9″ with square shoulders. In this condition it broke after 276,000 revolutions under 30,000 pounds stress. The fracture took place at one of the square shoulders, the crack forming a ring concentric with the shaft. The shoulder also reduced the strength about 40 per cent. The stresses are estimated on the net section; *i. e.*, the strength in this case was 40 per cent. less than what it would have been if the whole shaft had been turned down to the diameter of the smallest section. Another steel shaft, No. 22, from the same steel as Nos. 21 and 24, was treated the same as No. 29, and after withstanding 8,000,000 revolutions under 20,000 pounds stress,

broke after 689,000 revolutions under 25,000 pounds stress. The reduction of strength here is also 40 per cent. No. 30, from the same steel as No. 29, was treated like Nos. 29 and 22, and after withstanding 6,000,000 revolutions under 25,000 pounds stress, broke after 629,000 revolutions under 30,000 pounds, the fracture occurring at a square shoulder as before. Nos. 22 and 24 were a soft steel of .08 per cent. carbon, and 62,600 pounds tensile strength. Nos. 29 and 30 were a hard steel of .485 per cent. carbon, and 104,500 pounds tensile strength. The strength of both under these repeated stresses was reduced about 40 per cent. by such grooving and shoulders as described.

Flange Couplings.

The subject of Mr. Bowen's thesis was, "Tests of Flange Couplings under Repeated Stress." The dimensions of the couplings tested

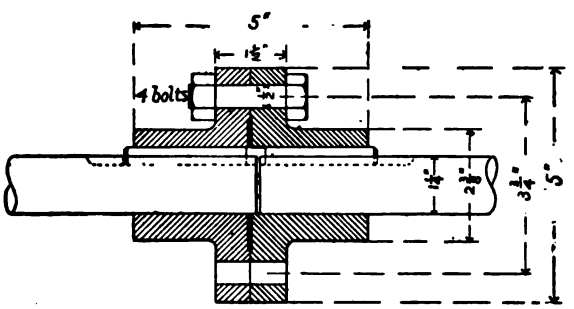


Fig. 4.

are given in Figure 4. They were proportioned in all their details according to the rules given in Machine Design, and were made with due care. They were tested in the repeated stress machine with a view to determining the efficiency of the joint and the weakest point in it under such stresses. Wrought iron and steel shafts $1\frac{1}{4}$ inches in diameter were tried. The wrought iron had a tensile strength of 50,700 pounds, with 15 per cent. elongation in 10″, and the steel a tensile strength of 62,200 pounds, with 20 per cent. elongation in 10″. The solid shafting was first tested. The wrought iron solid shaft broke after 2,500,000 revolutions under 26,000 pounds stress, and the steel after 1,000,000 revolutions under 38,000 pounds stress, it having previously withstood 10,000,000 revolutions under 36,000 pounds stress.

The couplings were then tested by joining two pieces of shaft together, and testing as for a solid shaft. Three couplings were tested, two with steel shafts, one with wrought iron. In all cases the shaft fractured, the parts of the coupling showing no signs of weakness. In all cases the break occurred at or near the edge of the boss, the crack starting apparently at the edge of the keyway. The position of the crack is shown in Figure 5.

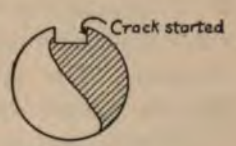


Fig. 5.

The stresses at which fracture occurred are as follows: With steel shafts, one broke after 2,740,000 revolutions under a stress of 20,000 pounds. The other withstood 10,500,000 revolutions under a stress of 16,000 pounds, and then broke after 5,000,000 revolutions under a stress of 18,000 pounds. With wrought iron shafts, fracture occurred after 2,400,000 revolutions under a stress of 20,000 pounds. It would appear, therefore, that the wrought iron and steel under these conditions had about the same strength. If we take 18,000 pounds for the breaking stress, this is about 35 per cent. of the tensile strength of the iron, and less than 30 per cent. of that of the steel. Comparing with the strength of the solid shaft under repeated stress, the strength of the steel shafting was reduced fully 50 per cent. by the coupling, and that of the wrought iron shaft about 23 per cent. In other words, the efficiency of the couplings under repeated bending stresses was, for the steel shafting 50 per cent., and for the wrought iron shafting 77 per cent.

The local conditions which determined the position of the fracture were evidently the keyway, and possibly the pressure of the coupling boss. The conditions in these tests are similar to the case of a pulley or fly-wheel keyed to a shaft.

From the cases mentioned it appears that small imperfections in the metal have a noticeable effect in causing fracture under repeated stress. The importance of having the metal free from flaws and bruises is evident. The bad effects of square shoulders in shafting, axles, etc., are quite generally known to engineers, but the extent to which the strength is reduced by such conditions may not be fully appreciated. In such a connection as a flange coupling, the problem, so far as strength is concerned, is to connect the two shafts with as little reduction in strength, compared with the strength of the solid shaft, as possible. We also wish to know the amount of reduction of

strength in any given case. When the piece is to be subjected to repeated stresses, tests under similar conditions are evidently necessary in order to determine the strength of the joint. A more important case is that of riveted joints. They are often subjected to repeated stresses, yet their resistance to such stresses has never been investigated. The information we have to depend upon is that obtained by pulling the joints apart in an ordinary testing machine. It is improbable that the proportions which will give the greatest efficiency under such tests would be most efficient under repeated stresses. The same criticism applies to the determination of the relative value of punched and drilled holes.

The usefulness of the ordinary tests when properly interpreted is unquestioned, but there are many points in design which cannot be determined by such means. The tests discussed cover, of necessity, a very limited field. The influence of chemical composition, heat treatment, etc., has not been touched upon. Also, there are repeated direct tension, compression, torsion, and other stresses to be considered. The field is practically limitless. For this reason, also, importance was attached to the study of the elastic changes produced; for a thorough knowledge of the nature of the accompanying internal changes would simplify further investigations, and make the facts already obtained more available.

DISCUSSION OF PROFESSOR SONDERICKER'S PAPER ON REPEATED STRESSES.

By JAMES E. HOWARD, Watertown Arsenal.

Read January 12, 1899.

Professor Sondericker has presented a valuable paper on a specially interesting field of inquiry, and I have been gratified to observe the close harmony existing among the results presented by him, and those which have been developed at the Watertown Arsenal.

In the Watertown tests two principal objects have been in view, namely, to ascertain the total number of repetitions of stresses necessary to cause rupture, and to observe through what phases the physical properties of the metal pass prior to the limit of ultimate endurance. The Watertown tests have included cast iron, wrought iron, hot and cold rolled metal, and steels ranging in carbon from .10 per cent. to 1.10 per cent., also nickel steels. The fiber stresses have ranged from 10,000 pounds per square inch on the cast iron bars up to 60,000 pounds per square inch on the higher tensile strength steel bars.

The specimens were in the form of rotating shafts subjected to transverse loads. The speed of rotation was from 400 per minute up to 2,200 per minute in different experiments. Observations were made on the deflection of the shafts and on the sets developed. It was early observed that intervals of rest were followed by temporary reduction in the magnitude of the sets. The Report of Tests of Metals for 1888 takes up this feature. Deflections were measured under different fiber stresses, both when the shafts were at rest, and when rotating under high speeds.

Quoting from the above-mentioned report, "the deflections tend to diminish under high speeds of rotation when the loads exceed the elastic limit of the metal, and tend to cause permanent sets; but, on the other hand, when the elastic limit is not passed, the deflections are the same within the range of speeds yet experimented upon." This quotation marks the distinction between deflections when elastic

strains only are involved and cases of permanent sets. Efforts were inaugurated at this time to ascertain the effect of repeated alternate stresses on the tensile properties of the metal, and it appeared that such treatment tended to raise the tensile strength of the metal before rupture ensued.

Subsequently, in 1892, annular forms of tensile specimens were taken out of the transverse shafts. The results with this form of specimen, wherein only the metal remote from the neutral axis was examined, confirmed the earlier observations. The changes in tensile properties are most pronounced in the softer grades of steel, a fact quite consistent with the behavior of common tensile specimens, if we consider the stress per square inch on the section at rupture in comparison with the strength referred to the original area, or if we bear in mind the comparative effects of cold working on mild steel and on harder metal. It is not every test that furnishes an example of higher tensile strength in metal which has been subjected to repeated alternate stresses. Frequently incipient cracks have developed before the tensile test-piece is taken out, and then an apparent loss in tenacity is shown over the original strength. One favorable example will be referred to, taken from the results given in the Report of 1893. A cold-rolled steel shaft was annealed at 1,800° F., then tested for endurance under a computed fiber stress of 40,000 pounds per square inch, rupture occurring at 102,000 rotations.

The subsequent test by tension of this metal showed a tensile strength of 73,240 pounds per square inch for the part which had been exposed to the above-mentioned fiber stress, and 61,920 pounds per square inch for that part of the shaft which had not been exposed to those repeated stresses. The effect of higher temperatures in increasing the endurance of the metal was shown by a number of steel bars which ran at temperatures in the vicinity of 400° F., or above, the highest being 472° F.

The following table is taken from the Report of 1893, showing the relative endurance of hot and cold bars. From the wide range in carbon in these bars, and the fact that each of the hot bars largely exceeded in endurance its companion cold bar, we infer that these tests established the fact that the endurance at from about 400° to 472° F. is greater than at atmospheric temperatures.

It will be observed in this connection, that the tensile strength of steel is greater in the above zone of higher temperatures than at ordi-

Carbon.	Total Number of Rotations.	
Per cent.	Hot Bars.	Cold Bars.
0.15	85,200	4,350
.17	32,300	3,950
.34	127,700	11,600
.55	111,800	11,950
.73	218,500	34,900
.82	148,200	42,000
1.09	99,200	23,000

nary temperatures, while it is probably true on the other hand that the elastic limit is somewhat lower. It is certain that the modulus of elasticity diminishes with increase of temperature. These and other results lead to the inference that tensile strength is a function of the endurance of metals to repeated stresses, and logically we must extend the inference and conclude that rupture will not take place until the stress reaches the ultimate tensile strength of the material. Now since we rupture shafts under repeated stresses which do not appear to reach even the tensile elastic limit, it is necessary to offer some explanation of this seeming discrepancy. It is believed that a gradual introduction of internal strains takes place, and their cumulative effect, together with the external applied stress, is adequate to strain individual parts of the metal to their ultimate limit and cause rupture; and that rupture is not caused until such strain or corresponding stress is reached.

The greater mobility of steel at a blue heat, as shown by the lower modulus of elasticity, we might readily suppose to be a favorable condition to promote endurance, certainly when combined with a higher tensile strength. The effect of cold rolling, cold swaging, and wire drawing, is to increase tensile strength. Why should not repeated stresses have a similar effect on tensile strength? The former kinds of treatment introduce intense internal strains, why not the latter?

Concerning the limit of indefinite endurance to repeated stresses we know but very little. In most experiments rupture occurs after a few thousand repetitions, so high have been the applied stresses.

Examples are not uncommon in railway practice, of axles having made 200,000,000 rotations.

In order to establish a practical limit of endurance, indefinite endurance, if we choose to call it so, our experimental stresses will need be somewhat lowered or new grades of metal found.

Many of the arsenal tests have been made with a maximum fiber stress of 40,000 pounds per square inch. This load was found adequate to cause rupture, with less than 5,000,000 repetitions for all shafts experimented with up to a recent date, although in one instance a specially treated bar was tested which showed a tensile elastic limit of 117,000 pounds per square inch, and tensile strength of 151,000 pounds per square inch.

An exception to the above statement has now appeared in a bar of high manganese steel furnished by the Bethlehem Iron Company which has endured over 80,000,000 rotations under 40,000 pounds per square inch fiber stress, and the shaft is not yet broken. This bar has the following chemical analysis:

Carbon, .39%. Manganese, 1.82%. Silicon, .64%.

It has been subjected to special treatment by quenching from a high temperature and annealing. Associated with the question of indefinite endurance, is the problem of how to raise that limit in steels of different grades. Various combinations of physical properties may be imparted to steels, but they are not of a permanent character when examined by means of repeated alternate stresses.

A new apparatus has been made at Watertown for tests by repeated stresses, in which six specimens are under test at a time. An innovation in this machine is found in the provision made for applying longitudinal stresses in combination with transverse stresses on rotating shafts. The relation of the two stresses can be so adjusted that the shaft shall alternate between a maximum and minimum tension, a maximum and minimum compression, or any given values of tension and compression.

THE PLANNING AND BUILDING OF THE SOUTHERN STATION, BOSTON.

By GEORGE B. FRANCIS.

Read January 26, 1899.

UPON the railroad routes within fifty miles of Boston about 50,000,000 passengers are carried to and from Boston each year, nearly equally divided between the North and South stations.

The close approximate population within the fifty-mile, or say suburban limit, is 2,392,000. Within the same limit around Philadelphia it is 2,289,000; around Chicago, 1,188,000; around St. Louis, 874,000; and around New York. 4,754,000; New York only exceeding Boston. These figures show the reason for large terminal facilities in Boston, and the existence of the South Terminal station.

The engineering force appointed by the terminal company to carry out the construction of the South Terminal station reported for duty on the first day of July, 1896. Accurate surveys were immediately commenced, covering the area to be occupied by the station, and some of the surrounding territory also, for the purpose of carefully defining the boundary limits of the various private ownerships, and for making a complete topographical record.

As the expenditure for land was liable to be nearly double the expenditure for construction, this work was done with great care, and all the base lines were made to conform with those of the various railroad, city, and state departments who had established them through this territory for various purposes. A constant checking with these parties, eliminating disputes where they existed, finally resulted in a survey accepted by all as satisfactory. Detail plans of each piece of property were made for permanent record in plat book form, preserving all measurements and data obtained which could be of use as reference in any case. Location maps and descriptions of land taken were also made for file in the public records, as required by the terminal act.

While this work was going on, the chief engineers of the interested roads and the manager of the terminal visited various railroad terminal stations in Europe to make critical examination, and to acquaint themselves with the many details and ways of carrying on such stations abroad.

The architects also were preparing several exterior designs for a head-house, various schemes for the layout of the public rooms for the station, and endeavoring to determine a proper arrangement for the general offices to be used by the different roads.

A fund of information was also being accumulated for reference regarding American stations, and particularly those of Boston.

Borings were also made to obtain the best information possible about the strata within reach beneath the station.

It was early decided that the new station must be so built that the new motive powers, electricity and compressed air, one or both, could be used therein; that a large increase in suburban trains, due to smaller train units and more frequent service, could be had; and that every effort possible should be made to remove the handling of baggage from the passenger platforms.

About the first of October, 1896, the first general ground plan, embodying the ideas accumulated, both as regards the arrangement of the rooms in the head-house and the arrangement of the tracks and platforms, was made.

The first plans made contemplated only a single floor for train service; but after arranging as well as possible for the various controlling features, making numerous studies for the exclusion of baggage trucks from the passenger platforms, and developing several ways of expeditiously handling electric cars, considering both high platforms on a level with the floor of such cars and low platforms as an alternative, it was found that such unusual features tended to use up space, and that instead of thirty or more tracks, which it was hoped could be had, the number was reduced to twenty-eight. This was discouraging, as the old stations contained an aggregate of twenty-five tracks, and the increase of three only did not promise that opportunity for future growth that it was reasonable to expect.

There being no reasonable hope that a greater width of land could be secured, attention was directed to the possibility of divorcing the suburban, or short distance service, from the long distance service and placing the former at a different level, thus doubling the room for

tracks on certain areas. The first sketch of this sort diverted the proposed suburban tracks from the main approach tracks about a half-mile from the station, and by a gradually rising grade brought several tracks on either side of the train shed to a level about 24 feet above the main floor. These were to be stub tracks, like those on the main floor.

This arrangement did not do away with the necessary switch system for making up trains outside of the station for each floor level; and upon its development it was seen that if the elevated stub tracks could be connected in the form of loops, the train movements would be very much lessened and the number of switches at the entrance largely reduced. The extreme width of the station made the loop connection possible, and a plan was drawn accordingly. This was the first loop-track study. There was some doubt, however, as to the advisability of having upper platforms about 28 feet above the main floor (which would be the case if high platforms were used), both on account of the appearance of the structure, the difficulty of handling baggage, the nuisance from the smoke and steam of the locomotives below, as well as the advisability of avoiding stairs. The approaching grades were also steeper than was desirable.

The possibility of a suburban loop track service upon a floor beneath the main floor was next considered. As the main floor of the station was designed at that time to be only about 6 feet above the highest tides, it required to be raised to the highest level possible without the use of stairs at the entrances from the streets, which was prohibited. The main floor was raised 4 feet, and inclines were introduced at the entrances.

Even this placed the lower tracks, which were finally designed to be 17 feet below the main floor tracks, 7 feet below very high tides. This immediately introduced the study of water-proofing this great area to shut out the water. Due consideration showed it feasible to do this without prohibitory cost. Placing the loop tracks 17 feet below the main floor and using high platforms for this kind of service made easier approach grades, stairways of 13 feet rise instead of 28, as was the case with elevated suburban tracks, and simplified the handling of baggage, improved the appearance of the main floor, and did away with the smoke nuisance.

The main station building was also drawn, set back from Summer Street, so that inclined approaches could be had to or from the first

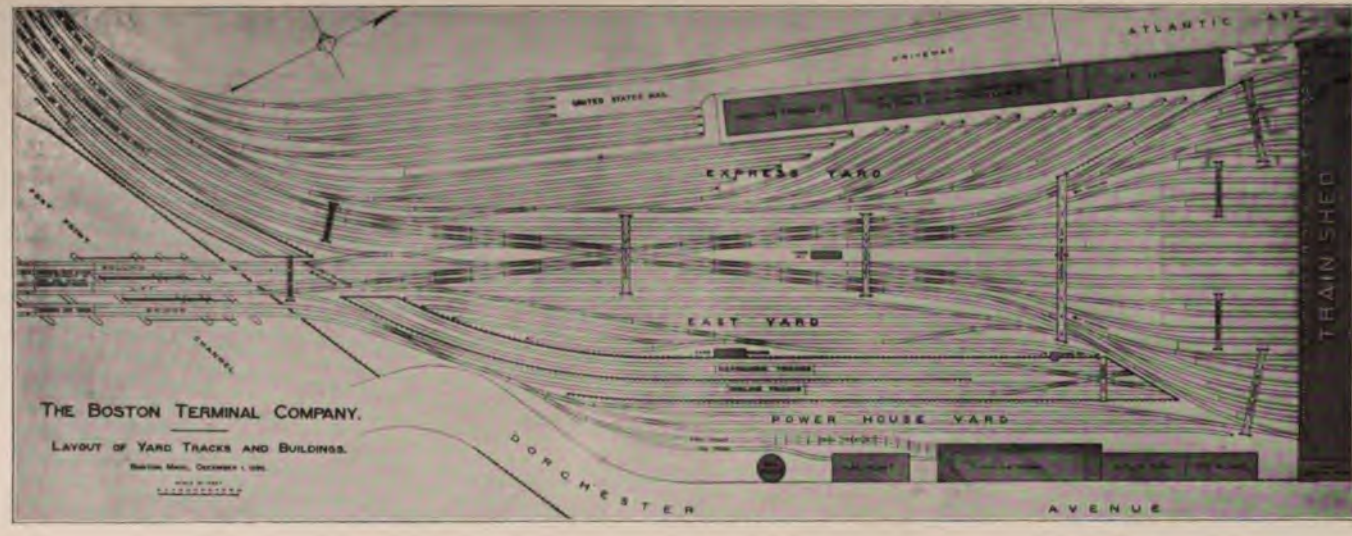
loop track, as well as to the main floor. Stairways were drawn from the main floor to the lower floor, so that all persons taking loop trains at the station could reach them by going down stairs only.

Before the loop plan was adopted it was drawn in various ways and positions, sometimes with two loops, sometimes with four, sometimes with curved corners, and some straight tracks; also tracks curved throughout. Studies were made of methods of handling the passengers and building the cars.

The one great feature which made the loop system attractive was the making of this great terminal a through station for one kind of service and a terminal station for the other. Suburban trains do not carry mails, express matter, or baggage in any quantity. They carry people only, and should be run frequently and got out of the way rapidly. The through station idea makes it possible to handle as many trains at the terminal as it is possible to run over a main line. Trains leave their passengers and move on without switching. If the coming motive power is electricity, through a third rail, it does not conflict with the immense switching system which must be maintained at so large a terminal.

As this station must eventually provide for suburban trains from four main lines — the Boston & Providence, Old Colony, New England, and Boston & Albany Railroads — such trains must leave the station at shorter intervals than trains could be run on either main line alone. This is provided for by arranging, with a minimum amount of switches, two loop tracks to be used alternately, each capable of holding several trains, one track to be filled while the other is being cleared. More loops meant more switches — the very thing to be avoided. By this means trains can remain in the suburban station much longer than the actual time interval between trains. These loops could have been arranged to operate with even less switches than designed, but it would have obliged all trains on some routes to use one loop track exclusively, whereas it was desirable to make the forward loop available for all routes to its full capacity.

After adjusting the loops, the arrangement for baggage handling was so drawn that there should be nine baggage and express trucking platforms the entire length of the train shed, independent of the passenger platforms, and an underground passage was designed to allow the baggage trucks to cross beneath the tracks. This method, which it is believed will very much reduce the baggage nuisance gener-



LAY-OUT OF YARD TRACKS AND BUILDINGS.

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ally experienced, requires seventeen baggage and express lifts, eight in the train house, four in the baggage rooms, and five in the express buildings.

Not the least of the station problems most vital to the successful operation of the station is the track arrangement necessary just outside of the station for the safe and expeditious handling of the trains. Alternative plans devised by various citizens for this situation omit this feature of the subject as one not requiring attention, or as a feature that may be treated as entirely subordinate to the station. The reverse, however, is the case, as the station is subordinate to the track arrangement.

There will be about 700 trains transferred to the new station from the old ones. An actual count at the old stations indicates about 4,000 movements in 18 hours each day through these switches. There will probably be more than this in a few years. It is believed that the arrangement adopted is simple and ample. By it the station may be operated as a unit, incoming trains on one side and outgoing trains on the other side, or in four sections, one for each of the four main lines.

Buildings have been provided for handling the mails and express, for supplying power to heat and light the station, also to make ice and Pintsch gas for the trains and for other purposes.

Having outlined the general features to be provided for operation, it became a question as to whether it was wise to incur the expense necessary to build the double floor station. Estimates showed that the cost of this additional floor, which, it was admitted, would nearly double the capacity of the station and provide a great reserve capacity whenever needed, would add only about 6 per cent. to its cost.

This additional cost was within reason, and the terminal trustees adopted this arrangement. On December 22, 1896, they submitted the plans to the mayor for his approval, which was obtained, and on January 4, 1897, the railroad commissioners, after several public hearings, placed their indorsement upon the plans. Two days later, on January 6, 1897, invitations were sent out for steel to be used in the train shed and track floors, and a contract was signed February 1, 1897.

That as much advantage as possible be taken of the winter weather, a preliminary contract was made for excavation and the driving of 2,000 piles on January 11, 1897. The sale and removal of

private buildings was begun, the New England railroad buildings having been removed during the fall of 1896.

Meantime architects and engineers were busily engaged in developing working drawings and specifications of foundations and superstructure for the main buildings and train shed, so that when spring opened the work could be vigorously prosecuted. Bids for this work were received, and on April 7, 1897, a contract was awarded for the larger portion of the work to a Massachusetts contractor, O. W. Norcross, the proprietor of a number of quarries, stone-working plants, and wood-working and other shops.

It was decided that pink granite from Stony Creek should be used for the buildings, which were to be partly of two stories and partly of five; that the train shed should consist of three spans and the midway of one span.

The ground underneath the building was originally overflowed by the ocean, and was later covered with docks, wharves, and buildings founded on cribs, walls, piles and rubbish, a large portion of which had to be removed. The entire structure necessarily stands on piles, of which there are about 26,000.

To exhibit the immensity of the undertaking, a diagram was prepared showing how twenty-four prominent buildings of Boston could be founded within the area covered by the main structure. A list of these buildings is as follows: Mechanics' building, City Hall, Public Library, Postoffice, Exchange building, Ames' building, Trinity Church, Old South Church, Old State House, Cadet armory, Masonic Temple, Hotel Touraine, Hotel Vendome, original portion of present State House, Faneuil Hall, Faneuil Hall market, Herald building, and the following minor buildings to fill the smaller spaces: Worthington building, Carter building, Waban building, Y. M. C. A. building, Hotel Copley, Hotel Austerfield, apartment house Le Brun.

At the time of starting the work public travel existed over streets to be abandoned, sewers were in use upon which it was necessary to expend upwards of $100,000 to readjust them to the new conditions, water pipes and hydrants were in service, telegraph, telephone, electric light, police, and fire alarm wires were in the way. Electric conduits and gas mains also encumbered the ground.

There were many leases of property not yet expired, even after extinguishment of owners' titles. All of the coal in the great coal pockets, some of which were in the act of loading up from vessels, as

THE PILE TEST.

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well as all the stock and machinery in the various buildings, had to be removed before the buildings could themselves be torn down. All of these obstacles and many more were gradually overcome, and the razing of the buildings proceeded as if by magic. On February 5, 1897, a loading test was made to demonstrate the carrying capacity of spruce piles in the underlying strata. This load was 60 tons of pig iron upon three spruce piles, driven 27 feet into the ground, with a penetration of 3 to 4 inches at last blow of 2,000 pound hammer falling 16 feet, with the hammer line attached, and not exceeding 10 inches at any one blow for whole depth; proposed final load, from completed structure, to be 50 per cent. of the test load, which latter gave no resulting settlement.

The coffer dam which it was necessary to construct, and without which it would have been impossible to have executed the work, merits a brief description.

As the borings show an underlying stratum of clay within reach of a single length of timber, it was evident that a continuous timber wall driven into this clay close enough to prevent the leakage in the joints would positively exclude the water. With this sort of a wall surrounding the work no trouble would result in execution. In some places this line of timber wall, consisting of 6-inch splined hard-pine planks, in about 40 feet lengths, was doubled to give sufficient lateral strength to resist pressure from open water; at other places it was a single line.

Wherever this sheet piling was driven it was necessary to first entirely remove any stone or timber in the way. Any failure to do this was disastrous. There were some exasperating delays in the removal of the obstructions, obliging the use of several divers and a wrecking outfit, but eventually the entire terminal excavation was shut off from the salt water on three sides, and in some pockets on four sides, with this timber wall.

From the very start up to the present date there has been no flooding of the lower floor, the coffer dam having effectually done its work. The cost of this dam has been about $75,000. It is also of use in connection with the permanent shutting out of high tides, thus reducing excessive pressure on the water-proofing. By some it has been considered that the coffer dam presented the most difficult feature of the undertaking, and that without success in this particular it would be impossible to execute the work.

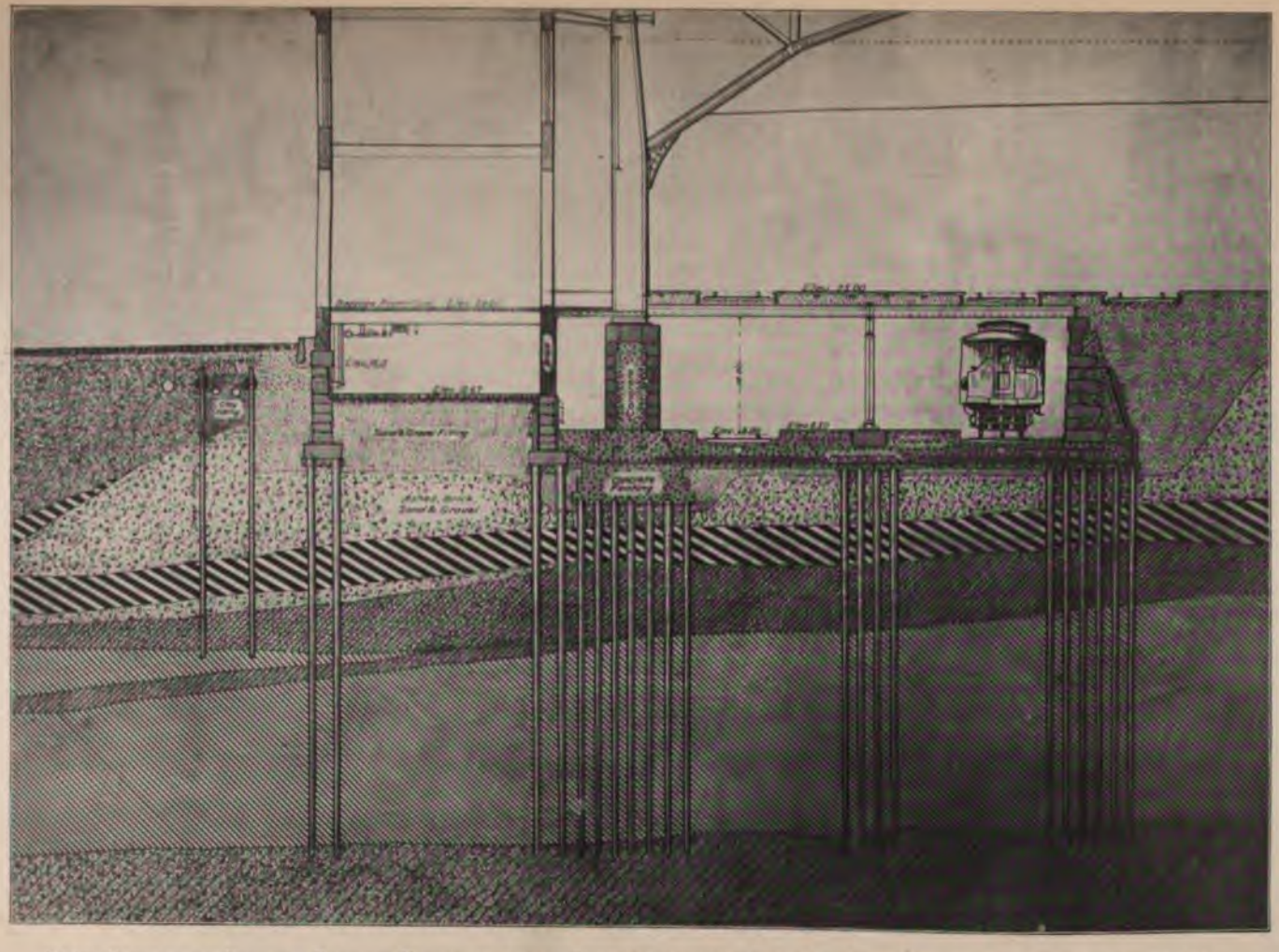
The permanent water-proofing sheet, which underlies the whole lower floor, consists of ten layers of tarred paper, swabbed together with hot coal tar pitch. The layers are carefully lapped, and all built in place. This continuous sheet of water-proofing, amounting to 56,000 square yards, or upwards of 10 acres, is laid, where horizontal, upon a concrete base, trowelled to a smooth surface. In some of the softer places boards were laid down under the concrete base, but usually this base, 6 inches thick, rests upon the ground. Where the water-proofing is on the vertical walls, it is backed up with 8 inches of brick work. In all cases the horizontal sheet lies between the pile heads and the granite masonry above.

Upon the water-proofing sheet where it is not weighted down with walls, there is placed a loading of a cheap grade of Portland cement concrete, sufficient to resist the upward pressure of the water, which is, on the horizontal layers, about 500 pounds per square foot, this pressure being dependent, of course, on the elevation of the sheet, with reference to the ground-water level. In some places the weight of the walls is far in excess of the water pressure; in others, where possible, the pressure is resisted by inverted concrete arches. The water has been more effectually shut out by this sheet than was ever expected.

A drain-pipe channel underlies each loop track for its entire length, and these discharge into the sump well near the power house, where both rain water and any leakage through the water-proofing finds its way, either through the automatic tide gates at low tide, or is pumped at other stages of the tide into the Fort Point channel by means of two submerged centrifugal pumps, operated by electric motors and automatic floats. These pumps are capable of raising 5,000 gallons a minute, or about 7,000,000 gallons per 24 hours.

The first steel was received in Boston, April 1, 1897. It continued to arrive, and a place at the southerly end of the train shed was cleared and graded to store it. Tracks were laid to this point, and the 900 carloads of steel were gradually deposited contiguous to the work. About 25,000 cubic yards of excavated material from beneath the head-house was carried away into the country at the start, but all other excavated material of the 275,000 cubic yards handled has been used in the filling required around the terminal.

During the months of April, May, and June, 1897, the city of Boston made a start at several points on the construction of the sea



Cross Section of Eastern Part of Foundation and Subway, showing Strata Penetrated by the Piling, Coffer-Dam, Waterproofing, etc.

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wall built by it along Dorchester Avenue. Grades were also fixed for all the streets surrounding the new station.

On June 28, 1897, a contract was made for the general mechanical and electrical equipment of the station, divided into the following heads: Interlocking plant and signals, boiler plant, engine plant, ice plant, lighting, arc and incandescent, heating, cold water and refrigeration, ventilation, hot water for cleaning, air for brake testing, elevators, steam heat for cars, protection for roof conductors, fire protection and pumping plant. Negotiations for this comprehensive contract had been under way for about six months, and the decisions reached were arrived at only after long and careful study.

The granite used in the work has been brought from the following quarries: Stony Creek, Connecticut; Milford, Massachusetts; Rockport, Cape Ann, Massachusetts; Pigeon Cove, Cape Ann, Massachusetts; Mt. Desert, Maine; Croacher's Island, Maine; Deer Isle, Maine; Northbridge, Massachusetts; Fitchburg, Massachusetts; Pascoag, Rhode Island; Milford, New Hampshire. In addition to this, large quantities of granite from Quincy, Massachusetts, found in the old work has been used again.

On October 16, 1897, the Terminal Company was enabled to take full possession of Federal Street, between Essex Street and Kneeland Street. Greater progress could have been made if the streets could have been obtained earlier, but many things stood in the way of this. On December 4, 1897, a contract was made for steel rails. On December 20, 1897, a contract was made for the covering of the entire train shed and connecting roofs, followed later by a supplementary contract for all the platforms. This roof work was started at the terminal March 18, 1898.

The train shed is lighted through asbestos covered wire glass, bedded in putty, fastened in with wooden strips in wooden sash, fastened with brass screws to wooden frames bolted to the train shed steel. All the glass is set vertically, and permanent foot walks have been provided, so that it will be possible to reach each pane of glass in the shed at any time with brushes and water to keep it reasonably clean.

The main roof is an asphalt and gravel roof, the gravel being the white Long Island beach gravel. The monitors are covered with copper. The roof is designed to carry with perfect safety a uniformly distributed load of 60 pounds per square foot, including its own

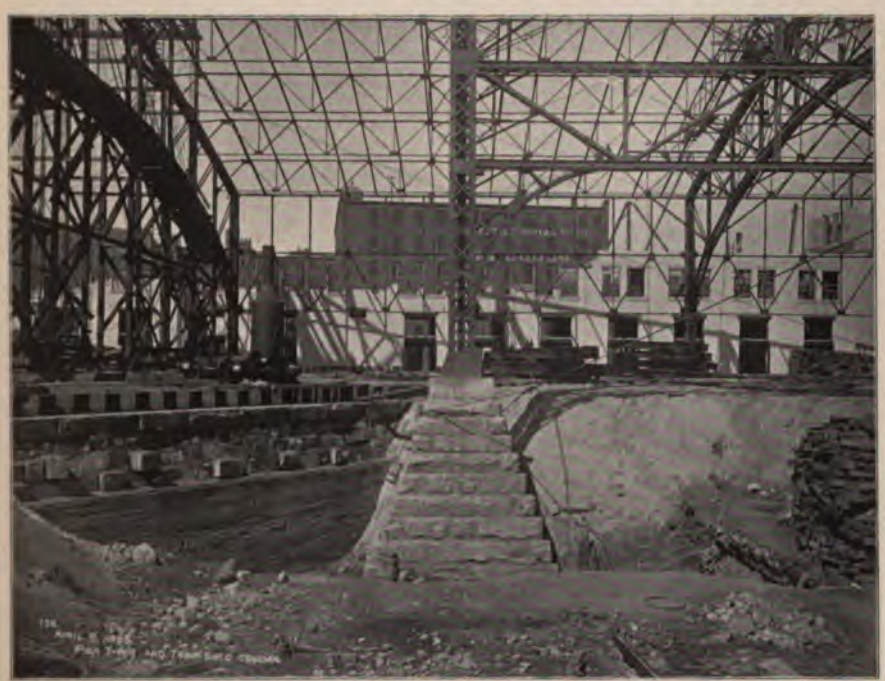
weight and several times this load before there is danger of rupture. The steel in the frame weighs about 23 pounds per square foot, and the coverings about 10 pounds more. It is not intended that it shall be necessary to shovel any snow from the main roof. All the down spouts are covered with jackets, and steam pipes have been run between the pipes and the jackets to keep them from freezing in the coldest weather.

On January 14, 1898, a contract was made for frogs and switches. These were delivered in July, August, and September, 1898. On February 5, 1898, a contract was made for the power-house buildings and subway work southerly of the main buildings, followed later by orders for the gas building and the express buildings. On March 3, 1898, a contract was made for the Pintsch gas plant.

From time to time orders were placed for ballast, ties (both ordinary and special), track fastenings, water connections and stand pipes, drains, and for many other minor details.

On March 7, 1898, the first pair of trusses for train sheds were erected ready to stand alone. On April 6, 1898, a contract was made for the sea wall along the Fort Point channel west of Federal Street. On June 9, 1898, Mt. Washington Avenue was closed to travel. On July 11, 1898, Federal Street, from the bridge to Kneeland Street, was abandoned by the city, and the extension of Dorchester Avenue was opened for travel. On November 4, 1898, the fires were lighted under the boilers, and on November 10, 1898, the first hot water was sent through the heating system.

The following brief statistics will give some idea of the multiplicity of details to be looked after in so large a project: Total area of terminal land, about 35 acres; total area covered by building, about 13 acres; maximum length of main station, 850 feet; maximum width of main station, 725 feet; average length of main station, 765 feet; average width of main station, 662 feet; area of main station, 506,430 square feet; area of awnings outside of buildings, 46,000 square feet; height of main station from sidewalk to top of eagle, 135 feet; length of express buildings, 712 feet; width of express buildings, 50 feet; length of power buildings, 569 feet; width of power buildings, 40 feet; total length of buildings on street front, 3,300 feet; length of train shed proper, 602 feet; width of train shed proper, 570 feet; height of train shed over all, 112 feet; train shed in three spans, middle span, 228 feet; two side spans, each 171 feet; trusses, canti-



PIER AND TRAIN SHED COLUMN; ROOF AND SIDE WALL OF SUBWAY, WITH BRICK BACKING, IS SEEN ON THE LEFT.

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lever, and 60 feet center to center; area of midway, 60,000 square feet; area of connecting roofs, 17,500 square feet; length of waiting room, 225 feet; width of waiting room, 65 feet; height of waiting room, 28½ feet; total length of tracks, about 15 miles; total number of tracks entering the station, 32; of these, 28 are on the main floor, and 4 in the shape of two loop tracks on lower floor; length of tracks under roof, 4 miles; number of tracks through throat in yard, 8 for main floor, 4 for lower floor; total weight of rail, 2,500 tons; number of double slip switches, 37; number of switches, 252; number of frogs, 283; number of semaphore signals, 150; number of signal lamps, 200; number of levers in tower No. 1, 143; number of levers in tower No. 2, 11; number of signal bridges, 9; total number of trains to use new station when fully opened, 710 per day; number of 65-foot passenger cars that can be set against platforms on main floor of station, 344; of these, 252 will be under roof; number of 40-foot passenger cars that can be set against platforms on lower floor, loop station tracks, 60, all under roof; the seating capacity for the above cars is 28,104 people; capacity of express yard against platforms, 26 express cars and 12 mail cars; total capacity of mail and express yard, 116 cars; capacity of other yard tracks, 93 cars, making a grand total of 613 cars.

In connection with the station there are 235 arc lights, inclosed pattern; 6,000 incandescent lights, 1,200 of which are in the main waiting room; 25 electric elevators, 209 water closets, 138 urinals, 118 set bowls, 5 shower baths, 106 fire supply outlets, 14 water meters, 29 storage vaults, 43 toilet rooms, 215 office rooms, 1,000 window shades, 200,000 pounds sash weights, 120 connections for supplying Pintsch gas to cars, 36 ticket windows, 95 baggage-room doors, 69 express building doors, 10 steam boilers, 4 electric generators, 9 compressors, 45 electric motors, 20 heating and ventilating fans, 25 steam engines, and 1 traveling crane.

The material used to complete the work approximates: 43,000 spruce piles, 15,100,000 common brick, 487,000 medium brick, 846,000 enamelled brick, 74,000 cubic yards concrete, 32,000 cubic yards stone masonry, 30,000,000 pounds or 15,000 tons steel, equal to about 1,200 car loads; 200,000 cubic feet of cut stone for building, or 500 car loads; 75,000 barrels Portland cement, 20,000 barrels Rosendale cement, 8,000 barrels coal-tar pitch, 6,500 barrels prepared asphalt, 850,000 pounds tarred paper, 450,000 pounds sheet copper for

roof trimmings; 5,000,000 feet B. M. yellow pine timber, for various uses; 16,000 pounds solder, 10 acres of gravel roofing, 150,000 square feet wire glass, 40,000 pounds or 20 tons of putty to set the same.

There are 56,000 square yards water-proofing, and about 200 acres of painting, reduced to single coat. The clock dial in tower is 12 feet in diameter, and the granite eagle is about 8 feet high, 8 feet wide, and 8 tons weight.

THE MECHANICAL EQUIPMENT OF THE SOUTHERN STATION.

By HENRY J. CONANT.

Read January 26, 1899.

FROM the preceding paper by Mr. Francis on the new Southern Station, one may obtain an excellent idea of the magnitude of the undertaking, for the conception and successful execution of which he is so largely responsible. The scale on which this work has been carried on is apparent on every hand, but to some of you nothing may be any more suggestive of the scope of the work than the fact that the mechanical equipment for the operation of the station, exclusive of all track and structural work, involves an expenditure of nearly three-quarters of a million dollars.

This equipment is far more complete and comprehensive than is provided for any other railroad station in the world. It comprises an extensive interlocking system for switching and signaling; a large power plant; elevators and lifts for carrying passengers and baggage; the warming and ventilating of the various buildings; a plant for making ice for use in restaurants and cars; a refrigerating plant for cooling provision boxes and storage rooms in the head-house; a plant for filtering and cooling drinking water; service for car heating; appliances for charging air brakes prior to the departure of trains; a high pressure water service for fire protection; a pumping plant for freeing portions of premises which are below tide water, from storm water or from possible seepage through water-proofed structure; provisions for preventing the stoppage of roof conductors by freezing; furnishing supplies of steam and hot water in the head-house, etc.

The engineering work involved in extended researches into the needs and experiences of the more important Terminals in this country and abroad, and in the preparation of detailed designs and specifications for a comprehensive equipment adapted to the requirements of the new Southern Station, was placed in the hands of Westinghouse, Church, Kerr & Company's engineers, representing in this case the

various Westinghouse interests. This was done at a sufficiently early stage of the undertaking to make it possible to remove obstacles of the kind usually encountered in work of this character, and to a considerable degree create conditions favorable to the best results, and much of the success which has been obtained may be attributed to the commendable foresight which led those in control of the enterprise to cause the mechanical engineering work to be treated in this comprehensive way. Although the provisions for the service at the new station are very extensive and unusually diverse owing to its size and particularly to the unique character of some of its more prominent features, the various portions of the equipment have been so successfully harmonized and made to relate one to the other so intimately, that a very considerable saving of apparatus and gain in simplicity and efficiency have resulted.

Power Plant.

The general arrangement of the power plant was largely determined by important considerations of track and yard facilities, leading to what some one has very aptly termed a "tandem" lay-out. The principal apparatus is contained in a building erected especially for the purpose, and occupying a space 460 feet long and 40 feet wide on the easterly side of the yard.

This plant furnishes power, light, heat, and refrigeration wherever required throughout the premises, and is the initial source of all the varied mechanical service that the station requires. Its design is based primarily on the principle of subdivision of power, the apparatus and size of units being chosen with special regard to the widely varying loads to be carried during different hours of the day and seasons of the year.

So far as possible, precautions have been taken to guard against accidental interruption of the service, and substantial relay has been provided throughout, either in the form of complete spare units or through a choice of units which permits of the loss of use of one without impairment of service. The steam piping is in duplicate in all its essential portions, but the arrangement is in such form as to avoid the complexity usually accompanying this feature of design, and at the same time allowing isolation and repair of any part without interruption.

View of Boilers and Stokers.

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Boiler Room.

The boilers are of the well known horizontal return tubular type, 72″ in diameter and 18′ long. They are made from an extra quality of steel specially rolled for this plant to meet rigid specifications and tests, and are designed for carrying a working steam pressure of 150 pounds per square inch.

The furnaces are provided with an equipment of Roney mechanical stokers, and are adapted to burning widely different qualities of fuel, including "front ends" from locomotives, and either high or low grade coals, with the greatest possible economy and without smoke.

The waste gases are passed through a pair of improved circulating economizers, with dampers and by-pass so arranged that they may be operated singly, in parallel, or in series with each other, as the conditions of service may allow, thereby permitting the greatest possible saving to be made at all times.

Draft is furnished by a pair of large, slow-running fans, either of which is of sufficient capacity for the entire plant. The products of combustion, cooled by the economizers to a point at which natural draft could not be employed (except by the use of a chimney so large that its cost would be prohibitive), are discharged at a point a few feet only above the roof of the boiler house through a short and inconspicuous stack.

Provisions have been made for a substantial increase in boiler capacity whenever required, and consideration has also been had to the future installation of coal handling machinery so far as expedient to do so.

Engine Room.

Owing to the fact that electric current is used for many purposes to a varying extent, the load conditions are complicated, and much consideration was necessarily given to the choice of units for the most economical and reliable performance of the work. An opportunity to use exhaust steam in varying amounts at different hours of the day and seasons of the year also had a substantial bearing on the character of the units employed. For the purpose of studying their conditions, elaborate load charts were prepared for average days for each month in the year, each service having its separate curve.

To best meet the conditions so presented, four 18–30 x 16 Westinghouse compound engines, aggregating 1,500 horse power, were

used, each directly connected to a 225 k. w. Westinghouse multipolar engine type generator, capable of simultaneously generating current in any proportion at two potentials; one of 220 volts for power, and one of 110 volts for arc and incandescent lighting.

So far as the demand for exhaust steam requires, these engines are operated non-condensing, but any or all may be run under vacuum as occasion requires, the arrangement of exhaust piping being such that the exhaust from any engine may be readily carried into either the vacuum or the atmospheric side of the system while running.

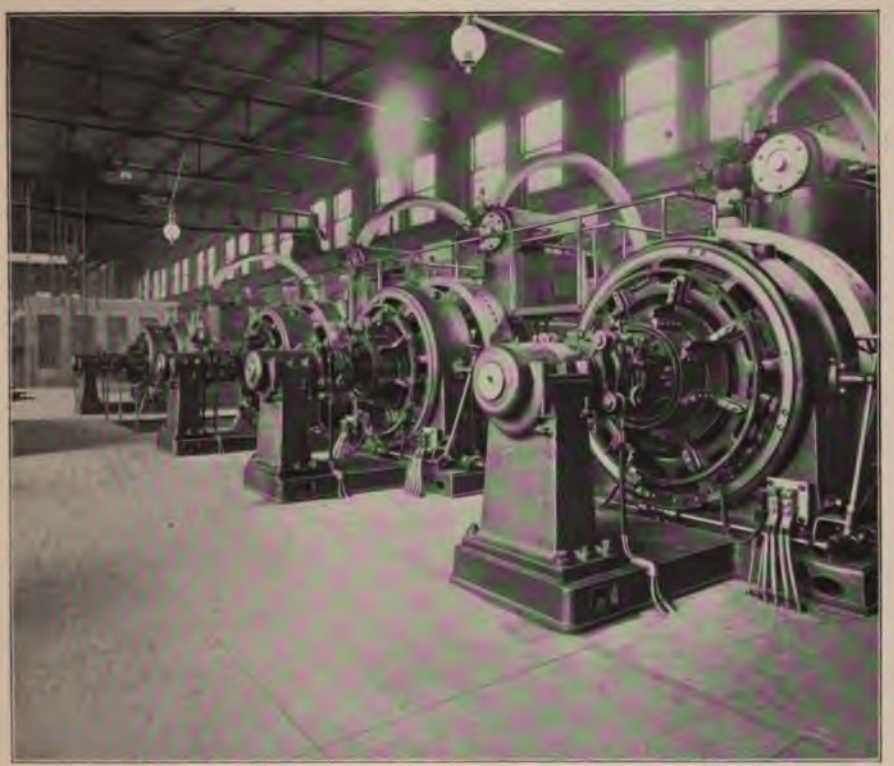
The design of the switchboard permits the separation of power and lighting service on a double set of bus bars whenever desired, and of carrying at will such pressure on any set of feeders as may be required to maintain a constant voltage at the principal distributing centers which have been established throughout the premises at a considerable distance from the power house. Outside of the features involved in the problem of "distribution," there is little in the electric wiring system that is of much more than ordinary interest.

All power circuits are run on a 220 volt two-wire system; 220 volt feeders are also carried to each of the distributiug points for the arc and incandescent lamps. Neutral balance wires are run from each of these distributing points and combined in a trunk neutral connecting through balance coils at power house with the generators, and providing a path to the armature circuits for any unbalanced load there may be in the 110 volt tap circuits.

All principal distributing centers are provided with annunciator systems and pressure wires connecting with suitable instruments on the main switchboard at the power house, and pilot lamps at the distributing boards serve to show when the board is alive after a call for current is made. The installation contains a total of considerably over 6,000 incandescent and about 250 arc lamps.

Interlocking.

The switching and signaling system includes a very complete installation of Westinghouse electro-pneumatic interlocking apparatus for handling all the trains of the railroads using the station to and from the main train shed, and for the frequent trains which are to use the tracks in the suburban loop. The switches and signals are both operated by compressed air furnished from the power house, and the operating mechanism is controlled electrically from inter-



Engine and Dynamo Room.

Compressor Room, Ice Plant.

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locking machines in the towers. Two interlocking machines are required for this work, and these are located in two interlocking towers built especially for their reception, and for the use of the men who are to operate them. Operating models of the tracks upon which each movement of the switches and signals is duplicated in miniature are provided at each machine, so that operators will always have before them the exact condition of the tracks under their control.

The signals are located in some cases on ground level, but are largely placed on nine signal bridges extending over the tracks and varying in span from about 50 feet to 120 feet. The signaling apparatus constitutes a complicated system somewhat similar to that in use at the Northern Station, but is more extensive and embodies a number of important improvements.

The principal objects accomplished by this interlocking system are to concentrate the operation of all switches at one point; to control movement of trains over them by use of fixed signals, also operated from a central point, interlocking the levers operating the switches and signals one with another, so that until all switches in a given route are properly set, the signal governing train movements over it cannot be "cleared," and conversely to prevent the movement of a switch while a signal governing a train movement over it is at "clear." This is accomplished through extremely ingenious combinations of mechanical and electrical devices which could not well be explained at length without models or recourse to elaborate details.

Car Heating and Air Service.

An extensive system of steam and compressed air piping has been distributed through the yards and train shed, and connected with the stub-tracks, for warming the cars while standing on the tracks in cold weather when the locomotive is detached, and to furnish a suitable supply of compressed air for the air brakes prior to the departure of the trains. This is an important feature in all terminal work, and in this instance is unusually complete.

Disposal of Water.

The disposal of water from the large extent of water-proofed structure involved somewhat unusual considerations, due to the fact that a large portion of the basements and all of the suburban loops are below tide water. A large sump well has therefore been built

near the power house in which electrically driven centrifugal pumps have been installed to pump away any possible seepage, storm water, and melting snows, which owing to the grades of the suburban track will necessarily be carried to the lower levels. The electrical pumping apparatus is controlled automatically by the level of the water in the sump, and a large reserve pump is provided to handle unusual quantities of water. Electric alarms are also provided to notify the power house attendants in order that they may start the large pump whenever the water might reach a predetermined danger level.

Heating and Ventilating.

A positive hot water circulating system connected with a central heating plant in the power house has proved to be an exceedingly satisfactory medium for absorbing and storing heat (from exhaust steam when available), and supplying it for warming some 2,700 or 2,800 linear feet of buildings located at considerable distances from the source of heat.

The circulating water is heated in three large tubular heaters, two of which are for the use of exhaust steam whenever available, and in the third, live steam is used at times when the quantity of exhaust is insufficient or wholly lacking. The water is pumped through these heaters and through the exterior circuit by either one of two steam driven centrifugal pumps. The main loop in the circulating system is about five-eighths of a mile long, and as the circulation is rapid and continuous, all portions of the premises are equally accessible with heat in any required quantity. Long bends are freely used to permit the large amount of expansion which necessarily occurs in the system, and to minimize frictional resistance.

All portions of the head-house buildings are ventilated with a degree of thoroughness seldom found except in that class of buildings to which the best type of modern school house belongs. This ventilation is secured independently of the means provided for warming the building, and it is really a matter of some note that a building devoted to railway and office uses and comprising nearly five million cubic feet of space should be accorded this treatment. Fresh air is supplied to the building by means of large fans of the blower type, located in basement heating chambers and driven by electric motors.

This building is warmed to some extent by direct heat, but principally by the indirect method. In all heating chambers, primary heat-

ers are provided for tempering the fresh air used for ventilation to 70 or 75 degrees according to conditions. This tempered air is blown directly through extensive systems of ventilating ducts to the various rooms in quantities to meet their requirements.

A portion of the air applied to those parts of the buildings which are warmed on the indirect method, is diverted from the main discharge of the fans and passed through supplementary heaters, also located in heating chambers, where its temperature is still further raised as weather conditions may require, and carried through entirely separate systems of ducts which parallel the ventilating flues, to points where they enter rooms, where mixing dampers are provided for controlling the amounts of tempered and hot air admitted at each outlet. The mixing damper is so designed that the total quantity of air supplied is not altered by its position, the effect of adjustment being merely to regulate the relative amount of hot air admitted through each register.

The form of building, its excessive proportion of exposed surface, and the very restricted space available for flues, made the matter of air distribution a much more difficult problem than usual, and necessitated the introduction of some uncommon features. Among these might be mentioned the necessity of insulating the hot air flues to prevent the loss of heat in passing over the great distances which have been necessary. The ventilation of the building is further assisted by twelve electrically driven fans located in the attics, exhausting the air from the rooms through flues connecting with the corridor spaces around the tempered and hot air ducts.

In all lavatories and sanitaries direct heat is provided for obvious reasons, and their ventilating ducts, and the exhaust fans with which they connect, are entirely separate from the rest of the ventilating system. These rooms are in all cases adjacent to rooms supplied with fresh air under pressure, and the arrangement employed assures a positive movement of air toward and through the fixture vents into air-tight chambers connected by suitable flues with the roof fans.

Elevators and Baggage Lifts.

Electric power is used for operating all the elevators and baggage lifts. There are in all nineteen of these electric elevators, five of which are for passenger service, two for freight, and twelve for handling baggage between the upper and lower levels.

Ice and Refrigeration, Etc.

One of the most interesting features of the new station will be the ice making and refrigerating plants, the principal parts of which are located in one end of the power house building. In this ice plant 20 tons of "Diamond" ice is made each day on the plate system. This ice is to be principally used on the cars, and the extreme summer demands will be partially met from a large ice cellar where ice will be stored during the cool seasons of the year, when the demand will fall below the capacity of the plant.

The restaurant and kitchen boxes and storage rooms are to be mechanically cooled by a refrigerating plant, and the same plant will be used for cooling the supply of drinking water for general use. The drinking water is taken from the city mains and thoroughly filtered, and after being cooled by the refrigerating plant will be constantly circulated through a water system which will supply some twenty-five drinking fountains. In this manner it is intended to provide a constant supply of pure cool water, instead of the more or less untidy and often foul ice coolers, such as are commonly used in public places.

THE ECONOMIC RELATION OF THE PROPOSED DEEP WATERWAYS TO THE STATE OF NEW YORK.

By GEORGE W. RAFTER.

Read May 12, 1898.

THE position of New York State between the Great Lakes and the seaboard is such that any deep canal connecting the Great Lakes with the ocean at New York city must necessarily pass within its borders. There are absolutely but two possible routes: the one from Lake Ontario through the Oswego and Mohawk Valleys to tide water in the Hudson River at Albany, and the other from Lake Ontario through the St. Lawrence River to Lake Saint Francis, and thence across the country to Lake Champlain, and from the foot of that lake at Whitehall across the dividing ridge to the Hudson River at Fort Miller, and through that river to tide water at Albany. The Mohawk River in particular has been a natural highway for commerce since the first settlement of the region. Its improvement was proposed by the then Colonial Governor of the Colony of New York in 1768, but it was not until 1792 that any improvement was actually inaugurated, the Western Inland Lock Navigation Company being organized in that year for this purpose. George Washington was the first president of this company, although it does not appear that he ever took any active part in the company's business. Probably Washington's connection with the Western Inland Lock Navigation Company was due to the fact that he had successfully inaugurated the Chesapeake and Ohio Canal a few years previously. The Western Inland Lock Navigation Company improved the navigation of the Mohawk River sufficiently to insure at least 2 feet depth of water at all points during the season of minimum flow. This company built locks at Little Falls, and was doing considerable business in 1806–7, when the Erie Canal was first proposed. Its rights were finally purchased by the State in 1818, and the locks at Little Falls were operated under State auspices until the completion of that section of the Erie Canal. Looking backward from the present point of view, it seems quite probable that had the Western Inland Lock Navigation Company been organized on a broad enough basis, the New York State canals would have

been owned by a great corporation rather than by the state. It is quite possible that such ownership would have been an advantage in the end, because a large amount of vicious state socialism which has grown up in New York, in consequence of state ownership of the Erie Canal, would have been avoided.

Agitation for the construction of some more comprehensive system of transportation than that afforded by the Western Inland Lock Navigation Company began in 1806, and finally culminated in the act of April 15, 1817, which authorized the construction of the Erie Canal. This canal was completed to Lake Erie in October, 1825. Its original dimensions were 40 feet width at the water surface, 28 feet width on the bottom, and 4 feet depth. The original locks were 90 feet long by 15 feet wide. In the enlargement of 1835–62 the dimensions fixed upon were, water surface 70 feet, depth 7 feet, enlarged locks 110 feet by 18.

Boats navigating the Mohawk River in the time of the Western Inland Lock Navigation Company carried from 5 to 15 tons of freight, the exact amount depending on the stage of the water, and the direction in which the boats were moving. Boats navigating the original Erie Canal carried about 90 tons, while those fitted to the enlarged canal of 1835–62 have a burden of about 240 tons. The enlargement now in process, authorized by Chapter 79 of the Laws of 1895, increases the depth to 9 feet and lengthens the locks to 125 feet. These changes are expected to admit of the use of boats of about 400 tons burden.

Immediately following the completion of the canal to Lake Erie in 1825, there was developed a great activity in transportation matters. The original cost of the canal was about $9,000,000. The tolls returned to end of 1834 were nearly $11,000,000, or the return was $2,000,000 more than the investment in less than ten years from date of completion. The result of this great increase in business was that the officials managing the Erie Canal forgot entirely the real object of a state canal and managed the business for many years exactly as transportation companies manage their business; that is to say, under the authority of the legislature they taxed the traffic all it would stand, the same as private companies.

The question may with propriety be asked, why should not the state manage the business of a state canal exactly as transportation companies manage their business. The answer is, that as regards the

State of New York, right of way for the canal was taken without compensation, under the plea of benefits received. The original Canal Law of April, 1817, provided for the appointment of a board of Canal Appraisers, who were authorized to assess damages on property taken for canal purposes, taking into account in their assessment the benefits received. Under this clause the Canal Appraisers would view a piece of property necessary for canal right of way, and although the canal might pass through the middle of an estate, leaving barns and outbuildings generally, on one side of the right of way, and dwelling house on the other side, with ponds of water over the meadows at both sides, still the Canal Appraisers would reason about like this: It is true the canal cuts through the middle of this estate, and that the farm barns are left on one side and the dwelling house on the other, and there are ponds of water over the meadows on both sides; but a packet boat will come along and stop on the dwelling house side, and the proprietor and his family can go visiting by boat all through the state; or, on the other hand, a freight boat will tie up on the barn side, and the produce can be taken to market without trouble to the owner. Hence we conclude that the benefits are equal to the damages and we award nothing. On this kind of reasoning nearly all the right of way for the early canals was taken without any compensation to the owners, and this, too, although the Erie Canal has long since ceased to be in any degree a carrier of produce to market for the people who live along its immediate line. In the case of the Genesee Valley Canal where all the right of way was taken under this preposterous reasoning, the canal went out of existence twenty years ago, and the right of way so taken has been sold by the State to a railway company which now operates a railway thereon. It is because of the existence in New York State of such pestiferous state socialism as this that the author condemns the early policies of the Erie Canal. By way of illustrating, however, how completely sentiment in the State has changed, it may be cited that in the general Condemnation Law enacted in 1890, it is provided that "benefits received" shall not be taken into account in assessing damages.

The present deep waterways project has for its object the opening of a deep canal between the Great Lakes and tide water, as well as the deepening of intermediate points in the Detroit and St. Clair Rivers, etc., to such an extent as to permit of large boats passing from all parts of the Great Lakes to tide water. Under the authority of an

act of Congress passed March 2, 1895, President Cleveland appointed Messrs. James B. Angell, of Michigan, John E. Russell, of Massachusetts, and Lyman E. Cooley, of Illinois, commissioners to make inquiry and report concerning the feasibility of the construction of such canals as would enable vessels engaged in ocean commerce to pass between the Great Lakes and the Atlantic Ocean, and the most convenient location and probable cost of such canals, etc. This commission is known as the First United States Deep Waterways Commission. Owing to a lack of appropriation for that purpose, this commission was unable to make any surveys, but studied the question in its general scope, submitting an able report which was transmitted to Congress by the President, January 18, 1897.

In the report this commission assumes that all main trunk routes for inland navigation via the Great Lakes, intermediate connecting channels, and the Hudson River, originate at the head of Lakes Michigan and Superior, and terminate either at Montreal via the St. Lawrence River, or at New York via the intermediate channels and the Hudson River. In the opinion of this commission the natural route from Lake Huron, which may be reached from either Lake Michigan or Lake Superior, is via the St. Clair and Detroit Rivers. Lake Erie, an intermediate canal connecting Lakes Erie and Ontario, Lake Ontario and the St. Lawrence River to Montreal, or, via a connecting channel from the St. Lawrence River to Lake Champlain, thence through the divide between the head of Lake Champlain at Whitehall and the Hudson River at Fort Miller, and through that river to deep water below Albany, with an alternative line from Lake Ontario to Troy via the Oswego-Oneida-Mohawk Valley. Various other alternative routes are suggested, which, however, need not be considered at this time. The First Deep Waterways Commission considered that a ship canal route through Western New York along the general course of the Erie Canal would not be a desirable project, because it would involve from 120 to 140 miles more of artificial channel than the route via the connecting canal between Lakes Erie and Ontario and the Oswego-Oneida-Mohawk Valley. Such a route would further have the disadvantage of a large number of bridges crossing it, and many locks, while the conformation of the ground, necessitating a side hill location across lines of drainage for much of its course, would make expensive construction and involve greater risk in maintenance.

This commission considered that preferably the proposed connect-

ing channels should be made 30 feet in depth. After considering the various questions presented, the first commission concluded:

(1) That it is feasible to construct the intermediate canals and develop channels adequate to any scale of navigation that may be desired beteen the Great Lakes and the seaboard, and necessary to conduct through the same the domestic and foreign commerce, and that it will be wise to provide for a channel not less than 28 feet deep.

(2) The commission also conclude that the most satisfactory route is through the several Great Lakes and their intermediate channels, and the proposed Niagara connecting canal to Lake Ontario, from whence the Canadian seaboard may be reached by way of the St. Lawrence River, and the American seaboard by way of the St. Lawrence River, Lake Champlain and the Hudson River, or via the Oswego-Oneida-Mohawk Valley and the Hudson River.

(3) It is concluded, in view of the international character and relation of a part of the works that will be required, and of the riparian interests involved, that the examinations and projects in the carrying out of the work can be best accomplished through a commission possessed with certain limited international functions.

In October, 1897, a second Deep Waterways Commission, consisting of Major Charles W. Raymond, of Philadelphia, Alfred Noble, of Chicago, and George Y. Wisner, of Detroit, was appointed by the President to make the detailed surveys and examinations recommended by the first commission. These surveys and examinations are now in process.

The matter of deep waterways connecting the Great Lakes with tide water has also been reported upon by Major Thomas W. Symons, of the corps of engineers, in 1897. Major Symons discusses at some length the question: What can a great ship canal be reasonably expected to accomplish? According to his view there are three possible routes for a ship canal entirely within the United States, from the Great Lakes to the navigable waters of the Hudson River.

The first is from Lake Erie through the Niagara River to the vicinity of Tonawanda; thence by canal with locks to the Niagara River near Lewiston, or to some point on Lake Ontario; thence through Lake Ontario to Oswego; thence through the Oswego and Oneida Rivers to Oneida Lake, and through Oneida Lake and across the divide to the Mohawk River, the same as proposed by the Deep Waterways Commission.

Major Symons's second route follows the line of the Erie Canal from Lake Erie to the Hudson River, or this line so modified as to provide for a continuously descending canal from Lake Erie to the Hudson.

The third route coincides with the first from Lake Erie to Lake Ontario; thence through Lake Ontario to the St. Lawrence River; thence down the St. Lawrence to some point near Ogdensburg; thence across the State of New York to Lake Champlain; through this lake to Whitehall; thence across the divide between Lake Champlain and the Hudson River, and through the Hudson River to deep water. This Major Symons gives as a possible route only, at the same time expressing the opinion that it is not a practicable one because it is not believed that the portion of New York State lying between the St. Lawrence River near Ogdensburg and Lake Champlain is suitable for a canal location. After some study of the matter, the author agrees with the conclusion that this route is not a practicable one. In reality, therefore, Major Symons indicates two routes. Some of his more important conclusions are:

(1) That to justify construction, the benefits to be derived from any deep waterways project connecting the Great Lakes with the seaboard should be clearly shown to be suitably commensurate with the first cost, together with the cost of maintenance and necessary improvements.

(2) That any ship canal built should be entirely within the territory of the United States, and should terminate at a first-class American seaport.

(3) That domestic commerce is more important to consider than commerce destined to or from foreign countries.

(4) That a ship canal by the St. Lawrence route, or by the St. Lawrence-Champlain route to New York, does not fulfill the necessary conditions, and should not be considered by the United States.

(5) That the best route for a ship canal is by the Niagara River, Lake Ontario, Oswego River, Oneida Lake, and the Mohawk and Hudson Rivers; that is to say, so far as the canal across the State of New York is concerned, he considers the Oneida-Mohawk route of the Deep Waterways Commission the best.

(6) The amount of tonnage which may possibly be tributary to the ship canal is 24,000,000 tons annually — 18,000,000 tons transported eastward and 6,000,000 tons westward.

(7) That the present enlargement of the Erie Canal will, if all restrictions upon its use be removed, give commercial advantages practically equal to the commercial advantages to be derived from a ship canal. The author cannot but think that Major Symons did not study this point very carefully.

(8) Major Symons further believes that if the Erie Canal were improved by enlarging to a size sufficient for 1,500-ton barges, freight could be transported between the East and the West at a lower rate than could a ship canal be navigated by the large lake or ocean vessels. He places the cost of such enlargement at approximately one-quarter the cost of a ship canal. In the author's opinion the cost would be much greater than this, and the benefits not nearly so great as Major Symons has estimated.

(9) As one of his final conclusions, Major Symons expresses the opinion that the construction of a ship canal from the Great Lakes to the sea is not a project worthy of being undertaken by the Federal Government for the reason that the benefits to be derived would not be commensurate with the cost. In his view the suggested enlargement of the Erie Canal to take 1,500-ton barges would accomplish everything desirable to be accomplished at present.

In one point, at any rate, Major Symons's report is worthy of special commendation. Of all the authors who have written upon the deep waterways question, he is the first to have thoroughly realized that the water power of the State of New York was in any degree an important element of the problem. He points out that a thorough understanding with the people of the State of New York as regards the rights in water should precede action of any kind. In his opinion whatever authority controls the canals should have full and complete supervision over the water taken and used for water power purposes.

New York State has great interest in these several deep waterways projects. New York City is the natural commercial emporium of the extensive region drained by the Great Lakes, and its phenomenal growth has been largely fostered by the commerce of that region. For some years there has been a serious decline in the quantity of grain moving to New York; the development of southern railway systems has taken large quantities to Baltimore, Newport News, and other shipping points. Moreover, a considerable portion of the decline must be charged to the short-sightedness of New York City merchants; they have been willing to remain middlemen merely. The

same unfortunate conditions also obtain at Buffalo, the western terminus of the Erie Canal, where elevator combinations have operated to the disadvantage of the canal business. As appositely remarked by Lyman E. Cooley, C. E., the Great West ought not to be made to pay toll at any toll gate between the interior and the ocean, the more especially when the toll rate is arbitrarily fixed. At both New York and Buffalo, charges upon the traffic have been in this predicament.

An interesting phase of the whole question is illustrated by the great decline in Erie Canal freights, and the growth of railway transportation. In 1896 the Erie Canal carried 565,000 tons of local freight in the State of New York, and the New York Central and Hudson River Railway 22,000,000 tons, the canal operating seven months in the year and the railway twelve months.

With the water resources of New York State fully developed, there is a possibility of about 1,500,000 water horse power. The deep waterways ought to be so designed as not to interfere very materially with the future development of all this power. Moreover, if this water, or that portion of it to be absorbed for canal purposes, can be made to produce more in manufacturing than it can in decreasing cost of transportation, then the people of the State of New York cannot afford to permit it to be used in transportation at all. In such a case a symmetrical development of the whole commonwealth demands its use in manufacturing. Its abstraction for navigation purposes would certainly work injustice to some citizens, even though it be true that transportation affects everybody. By way of illustrating what thorough development of water power can do for a state, we may compare the conditions in Massachusetts with those in New York. In the former state the census of 1890 shows that the products of manufactures are about two and one-half times as great per unit of area as in New York. The cause of this is chiefly that rational laws in Massachusetts have permitted the development of water power of that state to full capacity; every stream has storage reservoirs on its head waters. In New York State, on the contrary, almost nothing has been done in the line of such development.

[The reading of this paper was accompanied by the exhibition of 125 lantern slides illustrating the Erie Canal and water power developments in the State of New York.]

NOTES ON THE HYDROLYSIS OF CELLULOSE BY ACIDS.

By G. W. ROLFE and W. H. BARLOW.

Ever since 1819, when Braconnot[1] astonished the members of the French Academy by his exhibit of sugar made from linen rags, the scientific world has considered cellulose as a possible material for the economic production of sugar, because of the prevailing popular belief that the hydrolytic action of acids on this substance is strictly analagous to that on starch. Attempts to carry out this process on an industrial scale, however, appear to have always given absolutely negative results, or yields so low as to be of no practical use.

Nevertheless, it is an easy matter to repeat Braconnot's experiment of eighty years ago, which consisted in treating the linen at ordinary temperature with about twice its weight of concentrated sulphuric acid till the whole mass became a paste, and then after diluting with water to about a 2 per cent. solution, heating for ten hours. The neutralized solution on evaporation yielded dextrose.

Any attempt at more effective production by increasing the proportion of cellulose and decreasing the acid gave the opposite result. While in the aggregate much work has been done with every form of cellulose, as evidenced by the frequent allusions to the subject, the unprofitable outcome of such research seems to have discouraged the full and accurate accounts of what might have been important to the guidance of later investigation.

Flechsig[2] apparently was the first to define the conditions under which dextrose could be obtained quantitatively. He experimented extensively with sulphuric and hydrochloric acids acting on cotton wool, and showed that complete conversion to dextrose did occur, but in exceedingly dilute solutions — of $\frac{1}{2}$ per cent. strength — when the proportion of acid was at least twice that of cellulose. Flechsig's researches contributed much to our knowledge, and emphasized the

[1] Ann. Chem., 12, 172.

[2] Zeitschr. f. physiol. Chem., 7, 523.

fruitlessness of pursuing the ordinary methods of acid conversion for industrial purposes, at least so far as the economic production of dextrose was concerned. Flechsig's work is quite recent (1883). On this account it is interesting to note with what exactness the French chemist, three-quarters of a century before, had arrived at practically the only conditions of experiment favorable to complete conversion to dextrose.

Until very recently very little work has been done on the intermediate products of the hydrolysis of cellulose, at least so far as investigating their relation to each other and to the structure of the original cellulose. Braconnot studied the gummy substance formed by the action of concentrated sulphuric acid at ordinary temperature, as have Bechamp and Girard[1] and others. This body resembles starch paste in the characteristic blue color it takes when acted upon by iodine, but, unlike starch, the presence of sulphuric acid is necessary to the reaction.[2] No exact analysis of this substance has proved that it is a definite chemical compound, although it has been somewhat ambiguously termed cellulose hydrate or hydrocellulose by some authors. It is said to react with phenyl-hydrazine salts, and to reduce Fehling's solution.

It has also been observed that if an excess of the acid is used and the treatment prolonged, instead of the gelatinous body, a thick syrup is formed which is soluble in water in every proportion, and is not precipitated by alkalies, although it is by barium and lead salts. Braconnot appears to have studied this substance also, to which he gave the name "acide végéto-sulfurique,"[3] and Blondeau de Corolles[4] likewise worked on it and some of its salts.

Hönig and Schubert,[5] and more recently Sterne,[6] have made extensive researches on this combination, and found it to consist of a class of bodies which have been called cellulose-sulphuric acids, its composition varying with the conditions under which the cellulose is treated, changes in temperature affecting the reaction to a marked degree.

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[1] Ber. 12, 2,085.

[2] Liebig (Ann. Chem. u. Pharm., 42, 308) clearly defines the conditions of this reaction, in proving that this compound is not starch, and makes the observation that while starch is a certain test for iodine, the converse does not hold true.

[3] Loc. cit.

[4] Ann. Chem. u. Pharm., 52, 412.

[5] Monatsh. d. Chem., 6, 708, and 7, 455.

[6] Chem. Zeit., 1894, 185.

Hönig and Schubert have utilized these acids in the formation of a series of so-called "dextrins" which they have tried to identify by their optical and reducing properties. These "dextrins" were obtained by decomposing the cellulose-sulphuric acids formed under different temperature conditions, by precipitating with alcohol. By a similar treatment of starch they appear to have obtained "dextrins" practically identical with those from cellulose. Hönig and Schubert's work, while most interesting, throws little light on the mechanism of the hydrolysis of cellulose. This was to be expected if the analogy to the corresponding starch derivatives applied to any extent, as the latter "dextrins" are known to be complicated molecular aggregations of the primary products of conversion, their constitution varying with the relative proportion of these constituents, and possibly with the conditions of precipitation. They can only be resolved into primary carbohydrates by tedious fractional "precipitation" with alcohol.

An entirely different line of research had its origin in the discovery by Poumaréde and Figuier, in 1847,[1] of xylan or "wood gum," formed by the action of alkalies on wood fiber. These chemists supposed that what they had isolated was pectin. In the past twenty years this substance has been thoroughly studied, notably by Thomsen[2] and Koch.[3] Koch found xylan to be a close analogue of starch, and obtained from it by acid hydrolysis a sugar, xylose, radically different from dextrose. Wheeler and Tollens[4] established the constitution and optical constant of this sugar, showing conclusively that it was a pentose and not a hexose, as Koch's analysis would make it. Schulze, Stone, Fischer, and many others have studied xylan and its derivative, xylose, extensively. In fact these substances are most attractive subjects for research, not only to the chemist, but to the physiologist, from the almost universal occurrence of xylan in vegetable tissues and its consequent bearing on the chemistry of food.

Cross and Bevan[5] have made a study of the constitution of cellulose, more particularly of cereal straw, as interpreted by the products formed by hydrolysis. These chemists have concluded that, in the case of the cereal straws, acid hydrolysis, carried on for short periods at pressures of three or four atmospheres with dilute acids, separates

[1] Jour. f. pr. Chem., 42, 29.
[2] Jour. f. pr. Chem. (2), 19, 146.
[3] Phar. Zeitschr. f. Russland, 1886, 620.
[4] Ann. d. Chem., 254, 316.
[5] Tr. J. Chem. Soc., 1894, '95, '96, and '97; Ber., 26, 2,520, 27, 1,061, 28, 1,940, 2,604 Am. Chem. Soc., 17, 18; Chem. News, 73, 307

the pentose ("furfuroid") constituents quite completely from the hexose structure, the former going into solution; and further, that these "furfuroids" are "not pentosans, but products representing stages intermediate between the hexoses and pentosans."[1]

In this connection it is important to note the intimate relation existing between the hexoses and pentoses — the easy conversion of hexoses into pentoses by oxidation of terminal atomic groups, and escape of carbon as dioxide[2]; and the structural identity of the molecules of dextose and xylose according to Fischer's symbolism,[3] as well as the observations of DeChalmot.[4] These observations, also mentioned by Cross and Bevan, are that in plant growth dextrose appears to be paired with xylose, as is apparently galactose with arabinose. Another point worthy of mention is that there is some evidence going to show that the production of furfurol by distillation with hydrochloric acid is not exclusively characteristic of pentose compounds, although universally used for their quantitative determination. Wiley[5] speaks of small quantities of furfurol obtained from hexoses, and Storer[6] reports a not inconsiderable quantity in a single determination of granulated cane sugar, an amount much exceeding the limit of 0.2 per cent which DeChalmot gives for the furfurol yielded from hexose sugars under the conditions of analysis defined. It would be certainly within the bounds of possibility, considering the somewhat drastic means used in the extraction of xylan, and in the analytical methods for its identification, that under some conditions original hexose groups might be identified as pentose. It should be said, however, that this possibility has apparently not been considered by the majority of those who have worked on the pentosans.

The object of the investigation to be described in the present paper was to see what light could be thrown on the interpretation of the general scheme of acid hydrolysis of cotton cellulose, by methods already successfully applied to corresponding research on starch.[7]

Briefly, these methods consist in determining the specific rotatory and cupric reducing powers of the soluble products formed at different stages of hydrolysis, and graphically expressing the relations between

[1] J. Chem. Soc. Tr., 1896, 818.
[2] Wohl, Ber. 26, 744; Cross, Bevan, and Beadle, Ber. 26, 2,520.
[3] Tollens, Handb. d. Kohlhyd, 2, 15.
[4] Ber. 27, 2,723.
[5] J. Am. Chem. Soc., 20, 268.
[6] Bull. Bussey Inst., 2, 395.
[7] Rolfe and Defren, *Technology Quarterly*, x, 133.

these constants by a plot, the abscissæ of which represent rotation, the ordinates reduction. An arbitrary factor is used in determining the weight of carbohydrate present in solution, as is customary in starch research — .00386 — which is taken to represent the increase in specific gravity caused by each gram of carbohydrate dissolved in 100 cubic centimeters. We hoped by this means to define approximately the locus of a characteristic curve, which, if it did not make clear the nature of the hydrolysis, might indicate a direction for future research. It should be understood that the results obtained are necessarily approximations, but the purpose of this preliminary investigation being to study the general scheme of hydrolysis as a whole, absolute accuracy is unessential. Absorbent cotton of the best quality was the material experimented upon. The apparatus used in hydrolyzing was an autoclave arranged as already described in the paper referred to above.

The most important work on the hydrolysis of cellulose under pressure has been published by Cross, Bevan, and Beadle, reference to which has already been made, and by Simonsen.[1] The former do not define with much exactness any laws governing hydrolysis under these conditions, and Simonsen's work, for the most part, was done at pressures unattainable with our apparatus. We therefore made preliminary experiments for determining the conditions most favorable for effecting such hydrolysis as we wished, aiming to attain this with the least possible heat and acid, that decomposition might be reduced to a minimum.

(1) 110 grams of cotton were heated at two atmospheres (130°C.) for twelve hours in 1 liter of N/100 HCl. No appreciable increase in the density of the solution was observed, and on opening the autoclave the fiber appeared to be only slightly disintegrated. Under the microscope it showed no change.

(2) 110 grams of cotton in 2 liters of N/50 HCl were heated for fifteen hours at 5 atmospheres (158°C.). The solution was faintly colored, but the density did not increase perceptibly. Under the microscope the partly disintegrated fiber showed no change.

(3) 110 grams of cotton, 2 liters of N/20 HCl, 5 atmospheres (158°C.), ten hours. A faintly colored solution with finely divided fiber was found in the autoclave. No increase in the density of the solution was observed.

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[1] Zeitschr. f. angew. Chem., March, 1898.

(4) 110 grams of cotton, 2 liters of N/10 HCl, 5 atmospheres, ten hours. · A slight increase in the density was observed, and the beaker contained a brown friable mass showing no structure of cotton.

(5) 110 grams of cotton in 2 liters of N/10 sulphuric acid were heated for half an hour at a pressure of ½ an atmosphere. A sample was taken, and the pressure quickly raised to 1 atmosphere and kept so for another half-hour, at the end of which another sample was taken. Continuing this, successive samples were taken up to 8 atmospheres.

Several experiments were made along this line with sulphuric acid. In no case, however, did the resulting solutions warrant further investigation, owing to their low densities. These experiments showed conclusively that when the hydrolyzing acid has a dilution greater than N/10, and the pressure is less than 8 atmospheres, no perceptible amount of soluble conversion products are formed within seventeen hours. With stronger acid (normal sulphuric), after three hours, and even as low as two atmospheres pressure, the cotton undergoes a marked change, being disintegrated into a short, straight white fiber. Under the microscope it shows no twist, but the peculiar markings of the cell wall are still visible. The mass is friable, and closely resembles a crystalline deposit. Braconnot probably alludes to this substance when he speaks of the "pailletes" (spangles) which appeared after prolonged treatment of linen with boiling dilute sulphuric acid.[1] Cross and Bevan also mention it in their recent work on cellulose, but do not ascribe to it a definite constitution. They speak of it elsewhere as forming (representing) the hexose structure of the cellulose, if we interpret their statements correctly.

At higher pressures (6–8 atmospheres) we found that this white deposit is decomposed into a dark brown amorphous mass with a peculiar odor. This evidently being a complex decomposition product, we did not think it worth while to turn aside from the main line of research to investigate it further. We found that our results in general agreed with those obtained by Simonsen.

We experimented much with the gummy products obtained by the action of sulphuric acid in the cold, varying the length of treatment with the acid from a few minutes to several weeks, but obtained no more concentrated solutions by subsequent hydrolysis of these gums in the autoclave than we did with untreated cotton. Hence for our

[1] Loc. cit.

purposes, such preliminary treatment of the cotton offered no advantage whatever, although necessary for obtaining dextrose in quantitative amounts as previously stated.

The "dextrins" made from cellulose-sulphuric acid worked no better. It is unnecessary to go into the details of these experiments, as they offer nothing new, being carried out only so far as to establish this point to our satisfaction. The investigation of the hydrolized products was accordingly begun by a method of conversion described below, which was the best that our experience had developed. In this preliminary research we have made no attempt to define exactly the conditions of hydrolysis of each sample or to go into the subject of speed of hydrolysis.

In most cases, 50 grams of cotton was heated for four hours with 1,500 cc. of N/10 sulphuric acid at pressures varying from 1 to 8 atmospheres. The solution was then filtered from the deposit, which latter represented 90–92 per cent. of the weight of the original cotton, and neutralized with barium carbonate. When working at the higher temperatures it was usually necessary to decolorize with bone-black. These solutions were exceedingly dilute, as have been those obtained by other investigators.

These dilute solutions entailed such a large experimental error that we made an attempt to concentrate them by use of the vacuum pan. By this means we obtained solutions of densities corresponding to from 2 to 8 per cent. The evaporation was carried on at 700 mm. In every case more or less separation of substance out of solution took place. At first the solution colored somewhat, and as the evaporation proceeded, a brown substance was deposited on the (porcelain) pan. This deposit represented but a very small fraction of the whole, and was probably due to slight decomposition, but as it doubtless is derived from some of the lower products of conversion, its presence should be noted. To see how constant was the composition of the solution during evaporation, a series of samples were taken during this process, and the density and rotation taken. The plotted curve of the relation between the densities and saccharimetric readings of this series, making allowance for the inevitably large experimental error, was practically a straight line, as would be expected in concentrating a solution of constant composition. We felt justified, therefore, in leaving this deposit out of consideration in this investigation. Rehydrolyzing the dried residue left from a previous hydrolysis gave solutions of somewhat greater concentration.

Methods of Analysis. — All densities were calculated at 15° C. and corrected for influence of mineral matter present. Specific rotatory powers were determined from readings of the Schmidt and Haensch saccharimeter by a method already described in a paper on starch.[1]

EXPERIMENTAL DATA OF HYDROLYSIS OF COTTON CELLULOSE.

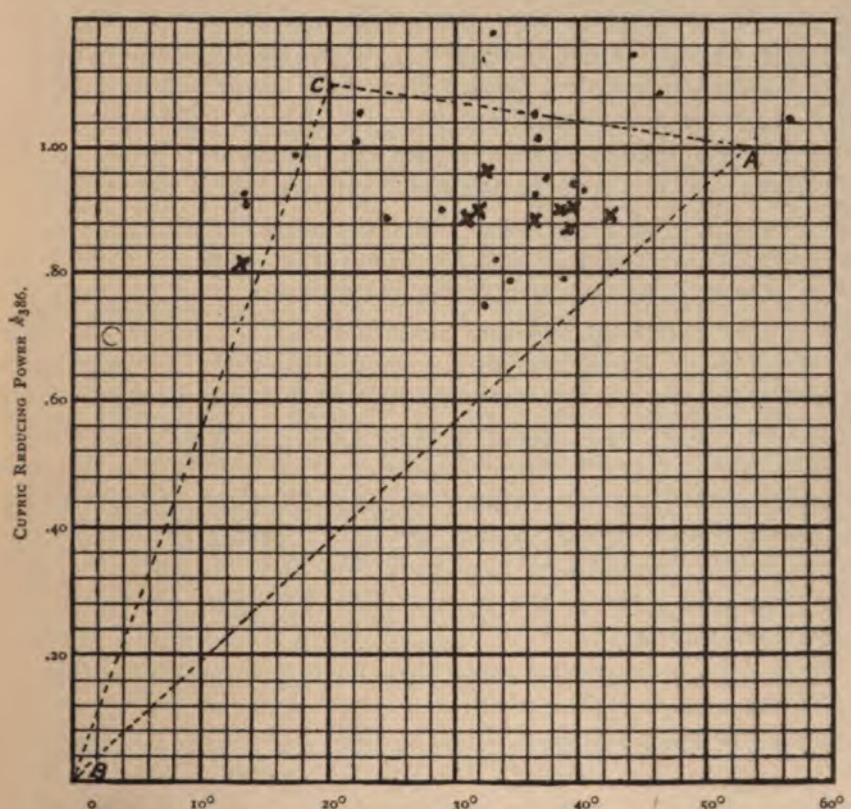
(Fifty grams of cotton with 1,500 cc. of N/10 H_2SO_4 cooked 4 hours at 4–8 atmospheres.)

No. of sample.	Corr. Specific gravity.	Sacch. reading.	CuO ($v' = \frac{1}{10} v$.)	Specific rotation $[\alpha]_{D386}$.	Cupric reduction k_{386}.
1	1.00418	1.40	.0764	22.2	1.013
2	1.00149	1.00	.0308	44.5	1.141
3	1.00243	0.50	.0335	13.7	0.935
4	1.00205	1.20	.0296	38.9	0.797
5	1.00202	1.10	.0387	36.2	1.058
6	1.00218	1.20	.0367	36.6	0.930
7	1.00390	1.70	.0640	28.9	0.909
8	1 00158	1.90	.0269	39.9	0.940
9	1.00185	1.30	.0368	46.7	1.098
10	1.00425	3.65	.0335	57.0	1.053
11	1.00710	2.40	.2585	22.5	1.025
12	1.00407	2.50	.0687	40.8	0.935
13	1.00231	1.29	.0425	36.9	1.016
14	1.00431	2.11	.0603	32.5	0.775
15	1.00610	3.45	.1050	37.5	0.957
16	1.00984	3.88	.1706	32.6	0.969
17	1.00713	3.63	.1059	33.8	0.825
18	1.01063	6.13	.1718	38.3	0.903
19	1.01201	5.32	.1731	29.4	0 805
20	1.00591	3.53	.0931	39.7	0.875
21	1.00388	2.02	.0552	34.7	0.788
22	1.02087	9.87	.1331	31.4	0.888
23	1.03086	14.87	.1995	32.00	0.9051
24	1.02442	15.59	.1557	42.38	0.8894
25	1.02155	12.80	.1402	39.45	0.9064
26	1.00443	1.81	.0317	24.37	0.8872
27	1.01191	3.07	.0760	36.43	0.8841
28	1.01156	2.23	.0665	13.03	0.8104

[1] *Technology Quarterly*, x, 133.

The method of copper reduction has also been described in detail in the same paper. A table of the analytical results is given, and the plotted data shown in the plate.

Great discordance is shown, as is to be expected from the necessarily large experimental error alone. As we have stated, if the solutions resulting from a first hydrolysis are removed, the residual



● = data of first hydrolysis.
X = data of hydrolysis of residual substance.

substance on further hydrolysis with fresh acid will yield solutions much more concentrated than can be obtained by one continuous hydrolysis. The data of these more concentrated solutions obtained by a rehydrolysis are shown as oblique crosses in the plate. It will be seen that seven out of nine of these plots approximate closely to a straight line forming the abscissa at .90.

Assuming that dextrose is the only optically active and copper-reducing body in the soluble substance, the plots of such impure dextrose solutions should approximate closely to the line *A B* (lying exactly on it, if the specific gravity factors of the impurities were the same as that of dextrose). As a matter of fact, they only approach it at a point corresponding to a practically pure solution of dextrose. The question naturally arises: What is the evidence of the presence of xylose as a product of hydrolysis? If we are to judge by the furfurol test, there is little. Koch[1] says: "No wood gum can be got from vegetable tissues that are free from lignin." Dobereiner and other earlier investigators obtained no furfurol from cellulose. Cross and Bevan[2] got 0.2 per cent. furfurol from bleached cotton.[3] Tollens and others have given substantially the same testimony.

The specific rotary power of xylose has been determined by Wheeler and Tollens.[4] Apparently no work has been done on the specific gravity factor, which we would expect to be a little less than .00380 for a 10 per cent. solution. Stone has made an approximate determination of the cupric reducing power of xylose, which makes it practically the same as dextrose, probably a little higher.

Taking k_{386} of xylose as 1.10, and a_{D386} as 20°, as defining the position of a pure xylose solution on the plate with sufficient exactness for our purpose, it can be shown that mixtures of xylose and dextrose in any proportion would form plots along the line *A C*. The line *B C* corresponds for xylose to the dextrose line *A B*, under the conditions defined for the latter.

It will be noticed that more than 80 per cent. of the plots lie within the triangle *A B C*; that all the plots of the more concentrated rehydrolyzed solutions approximate to a line parallel to the dextrose-xylose line *A C*, but below it. We deduce from these characteristics that the probability is strong that dextrose and xylose are the principal soluble products of the hydrolysis, and that at least one other body is present, probably in small quantity, and of weak reducing power and optical activity. If more than one substance other than dextrose and

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[1] Loc. cit.

[2] Chem. News, 68, 225.

[3] There is good evidence that these small amounts of furfurol result from an oxydation product, oxycellulose, formed in the bleaching of the cotton. (Witz, Bull. Soc. indus. de Rouen, 1882, 416. Nastjukoff, Bull. Soc. indus. de Mulhouse, 1892, 493. Cross, Bevan, & Beadle, Ber., 26, 2,520; 27, 1,061.)

[4] Loc. cit.

xylose is formed by the hydrolysis, of course we can merely say that the resultant of their influence on the optical activity and copper reduction is as above described. From the analogy of starch hydrolysis we would expect these carbohydrates to be in combinations with each other rather than in simple mixtures.

The outcome of this rough preliminary investigation is sufficiently encouraging for further work on these lines. We have succeeded in considerably diminishing the experimental error of other investigators, and while improvement in this is still to be desired, we are now enabled to outline a scheme of investigation which appears to promise results of some value. So far, the following conclusions are indicated: (1) The final soluble products of the acid hydrolysis of cellulose are probably, in the main, dextrose and xylose. (2) Intermediate conversion products which are practically insoluble, certainly much less soluble than the corresponding starch derivatives, are formed during the progress of hydrolysis. (3) By our method of hydrolysis less than 10 per cent. of the cotton is hydrolyzed into soluble products. (4) If the solution containing the conversion products of an hydrolysis is removed from the insoluble residue, the latter on further hydrolysis will yield solutions of greater concentration than could be obtained without such removal. (5) Preliminary treatment with concentrated sulphuric acid, by which the cellulose is gelatinized ("hydrated"), does not, so far as our observations go, seem to facilitate hydrolysis into soluble products.

We wish to acknowledge our indebtedness to Professor F. H. Storer for use of reference matter.

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TECHNOLOGY QUARTERLY AND PROCEEDINGS OF THE SOCIETY OF ARTS

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AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. XII. JUNE, 1899. NO. 2.

PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTY-SEVENTH YEAR, 1898–99.

BOSTON, January 12, 1899.

THE 519th regular meeting of the SOCIETY OF ARTS was held at the Massachusetts Institute of Technology this day at 8 P.M., with Mr. George W. Blodgett in the chair. Twenty persons were present.

The report of the previous meeting was read and approved.

Mr. Walter Humphreys, of Boston, Class of '97, Massachusetts Institute of Technology, and Mr. Edward D. Mellen, of Cambridge, Class of '94, Massachusetts Institute of Technology, were elected Associate Members of the Society.

The Chairman then introduced Professor Jerome Sondericker, of the Massachusetts Institute of Technology, who read a paper on "Repeated Stresses."[1] Repeated stresses are of very common occurrence in engineering structures. The moving parts of machines are, as a rule, subjected to them. Connecting rods and parallel rods, pro-

[1] Published in full, *Technology Quarterly*, Vol. 12, No. 1, March, 1899.

pellers, shafts, car axles, ordinary wagon axles, etc., are all subjected to repeated stresses. Car rails and the parts of a bridge are also subjected to varying stresses as the loads pass on and off.

When wrought iron or structural steel is tested in an ordinary testing machine by pulling apart in tension, by bending, crushing, etc., the piece is broken by a load gradually applied once. The material, being ductile, is considerably distorted before fracture takes place, the circumstances leading to fracture being those which accompany the flow of a plastic mass. The circumstances accompanying fracture under repeated stresses are entirely different, so that the strength of a piece under such stresses cannot be learned from the results of an ordinary test.

The tests presented were made on rotating shafts, subjected to a transverse load, the stress, therefore, varied during each revolution between tension and compression of equal amounts. The specimens tested included wrought iron and structural steel, the steel varying in carbon from .08 per cent., or less, to .50 per cent., and in tensile strength from about 45,000 pounds to about 100,000 pounds per square inch. The speed of rotation varied from about 350 to 500 revolutions per minute. With the exception of a few cold-rolled pieces, the metal was tested in the condition in which it came from the mills. The investigations were conducted along two lines:

1. The determination of the elastic changes resulting from the repeated stresses, and the influence of such changes in causing fracture.

2. The influence of form, flaws, and local conditions generally in causing fracture. These were discussed in turn.

Tables were shown describing the results of repeated stresses on different specimens, and deductions from these presented in a very interesting way.

Mr. James E. Howard, of the Watertown Arsenal, took part in the discussion which followed, giving a statement of results obtained by him in a somewhat similar series of experiments.[1] His conclusions were generally to the same effect as those of Professor Sondericker. Several other gentlemen followed him, among them Professor Lanza, who spoke of the importance of these experiments as affecting the determination of a proper factor of safety.

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[1] Published in full, *Technology Quarterly*, Vol. 12, No. 1, March, 1899.

BOSTON, January 26, 1899.

The 520th regular meeting of the SOCIETY OF ARTS was held at the Massachusetts Institute of Technology this day at 8 P.M., with Mr. Desmond FitzGerald in the chair. One hundred and sixty persons were present.

The report of the previous meeting was read and approved.

Captain Alfred E. Hunt, of Pittsburg, Pennsylvania, Class of '76, Massachusetts Institute of Technology, Mr. James P. Clare, of Quincy, Massachusetts, Treasurer of the Hatch Storage Battery Company, and Mr. Horatio N. Parker, of Cambridge, Massachusetts, were elected Associate Members of the Society.

The Chairman then introduced Mr. George B. Francis, Resident Engineer of the Boston Terminal Company, who gave a "Description of the Construction and Other Features of the South Terminal Station."[1] Various statistics were given, showing the necessity of the station, and a statement made of the leading features of the problem, which involved a terminal station for one kind of business and a through station for another. The through station idea makes it possible to handle as many trains at the terminal as it is possible to run over a main line, and is realized by the use of loop tracks. Previous to any construction, a coffer-dam, to shut out the water, which at high tide would flood the level of the loop tracks, was necessary. This was entirely successful, and was supplemented by a waterproof coating of ten layers of tarred paper, swabbed together with hot coal-tar pitch. A continuous sheet amounting to 56,000 square yards was laid on a concrete base. On this the structure was built.

Mr. Henry J. Conant was then introduced, and presented a statement of the mechanical equipment of the station.[2] It comprises an extensive interlocking system for switching and signaling; a large power plant; elevators and lifts for carrying passengers and baggage; the warming, ventilation, and lighting of the various buildings; a plant for making ice for restaurants and for cars; for filtering and cooling drinking water; service for car heating, for charging air brakes prior to the departure of trains, etc.

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[1] Published in full, *Technology Quarterly*, Vol. 12, No. 1, March, 1899.

[2] Published in full, *Technology Quarterly*, Vol. 12, No. 1, March, 1899.

BOSTON, February 9, 1899.

The 521st regular meeting of the SOCIETY OF ARTS was held at the Massachusetts Institute of Technology, this day at 8 P.M., with Mr. George W. Blodgett in the chair. One hundred and twenty persons were present.

The report of the previous meeting was read and approved.

The Chairman then introduced Mr. H. F. J. Porter, of the Bethlehem Iron Company, who presented a paper on "Modern Methods of Steel Forging," with illustrations by the stereopticon. He spoke briefly of the methods used in historical times in the forging of swords, armor, and other more domestic implements; then of the rapid development brought about by improvements in the manufacture of steel; and finally of the equipment at Bethlehem for forging, particularly hollow and solid shafts, dynamo field rings, guns, armor plate, etc. Views were shown of the hollow shafts of the "Oregon" and of the "Brooklyn," forged at these works.

BOSTON, February 23, 1899.

The 522d regular meeting of the SOCIETY OF ARTS was held at the Massachusetts Institute of Technology this day at 8 P.M., with Mr. George W. Blodgett presiding. One hundred and ten persons were present.

The report of the previous meeting was read and approved.

Mr. Thomas P. Curtis was elected an Associate Member of the Society.

The Chairman then introduced Colonel E. D. Meier, Engineer-in-Chief of the Diesel Motor Company of America. Colonel Meier read a paper on "The Diesel Motor,"[1] illustrating his remarks with lantern views of the engine.

This new form of internal combustion engine was first described by Rudolf Diesel in 1893. It does away with many of the difficulties of the gas and oil engines, and at the same time gives a much higher efficiency. Its essential feature consists of the adiabatic compression of atmospheric air to a sufficient temperature to ignite the fuel (usually petroleum oil) which is injected at a determined rate during part

[1] Published in full in another column.

of the expansion, or working stroke. By this means perfect combustion is obtained. The first experimental engines were built at Augsburg in 1894 and 1896, one of 12 and another of 20 horse power. Two engines have been built in this country, and many others will be constructed during the summer.

BOSTON, March 9, 1899.

The 523d regular meeting of the SOCIETY OF ARTS was held at the Massachusetts Institute of Technology this day at 8 P.M., with Mr. George W. Blodgett in the chair. Fifty-five persons were present.

The report of the previous meeting was read and approved.

The Chairman introduced Mr. Theodore H. Skinner, Massachusetts Institute of Technology, '92, recently Superintendent of Construction at the University of Virginia, for McKim, Mead & White, who read an appreciative paper on "The Construction of the University of Virginia, Old and New."

A description was given of the construction of the early buildings, and photographs were shown of the original designs by Thomas Jefferson, and then of the buildings as actually developed in the process of construction. A high tribute was paid to the artistic genius of Thomas Jefferson. After the disastrous fire that destroyed the rotunda, a generous sum was subscribed by alumni and friends. With this the rotunda was rebuilt and made fireproof, and three large laboratories added. While the total sum subscribed was large, the amount available for each building was rather small, and the architects were forced to use a cement and brick construction which has proved peculiarly fitted to the exigencies of the case. Cement has been used wherever stone would ordinarily be employed; for pillars, caps and bases, cornices, walks, floors, etc. Interesting problems were encountered in the construction, particularly in that of the great amphitheater, the floor of which is supported by reversed catenary brick arches. The entire work was copiously illustrated by photographs thrown on the screen.

A. T. HOPKINS, *Secretary.*

GEOLOGY OF THE WACHUSETT DAM AND WACHUSETT AQUEDUCT TUNNEL OF THE METROPOLITAN WATER WORKS IN THE VICINITY OF CLINTON, MASS.

By W. O. CROSBY.

Read December 8, 1898.

Introduction.

In connection with the operations of the Metropolitan Water Board in the construction of the Wachusett Reservoir on the south branch of the Nashua River and the Wachusett Aqueduct Tunnel, two miles in length, which is to convey the water from the reservoir obliquely through the eastern wall or ridge of the Nashua Valley on its way to Boston and the Metropolitan District, I have enjoyed, during the past three and a half years, exceptionally favorable opportunities for becoming acquainted with the geological structure and history of this part of the Nashua Valley. The scope of my studies embraces, first, the hard rocks, and particularly the geological structure of the eastern ridge in the vicinity of Clinton, as developed by surface observations, and especially by the exploration of the site of the main dam (known officially as the Wachusett Dam) by borings and the excavation of the Wachusett Aqueduct Tunnel; and second, the drift deposits, or glacial geology, for which there can hardly be a finer field in New England, especially as revealed by the deforesting of the area of the Wachusett Reservoir and the numerous borings in the vicinity of the proposed auxiliary dams or dikes. These strongly contrasted glacial and preglacial phases of the geology suggest separate description; and it is proposed, therefore, to consider here only the hard rocks of the district, reserving the glacial geology of this part of the Nashua Valley for a subsequent paper.

I am indebted to the Metropolitan Water Board, and to Mr. F. P. Stearns, the Chief Engineer of the Board, for the most unrestricted and ample opportunity to make these studies, and for permission to publish the results of general scientific interest. My acknowledg-

ments are also due to Mr. T. F. Richardson and Mr. H. A. Miller, Department Engineers of the Board at Clinton, for many special facilities and courtesies.

Under the auspices of the United States Geological Survey, Professor B. K. Emerson is engaged upon a detailed and systematic study of the preglacial geology of the part of Massachusetts embracing the Nashua Valley; and it is gratifying to know that this important work is in such competent hands and well advanced toward publication. The main purpose of the present contribution, therefore, is simply to supplement Professor Emerson's work, for a very limited part of his field, by a somewhat detailed presentation of facts, chiefly structural rather than lithologic, which have been gradually, and often only temporarily, disclosed during the prosecution of the engineering works, and which are now in large part inaccessible, and the records of which are buried among official archives.

South of the Fitchburg Railroad the dominant and determining geological feature of the rather sharply accentuated eastern ridge of the Nashua Valley is a narrow band of plutonic rocks, which forms the axis of the ridge and at most points its crest, rising like a great longitudinal dike through an extensive series of argillaceous strata. Even in their more normal phases these sediments, which also include some quartzite and, in the town of Harvard, an interesting development of conglomerate, are more or less metamorphic — argillites and phyllites or sericite schist; while in close proximity to the plutonic masses they are commonly altered to typical and highly crystalline mica schists. The phyllites and schists are also commonly more or less carbonaceous, pyritiferous, or calcareous; and chiastolite is a not uncommon accessory, becoming in some parts of the district a striking and distinctive feature of the formation. The general line of strike is north-northeast, parallel with the axis of the valley, and a steep westerly dip prevails; while through the central part of the valley, especially, the argillites are, in general, highly contorted and wrinkled. A closed or isoclinal syncline, with its axial plane dipping to the west, is thus suggested; and this view of the structure of the valley, with slight modifications, has been generally accepted by geologists since the region was first studied by Hitchcock, sixty years ago.[1] It is not to its synclinal structure, however, but rather to the relatively rapid

[1] Occasional Papers, Boston Soc. Nat. Hist., 3, 154–161.

erosion of the least altered and softest part of the sedimentary series that the valley as a topographic feature is immediately due; and the highly unsymmetrical profile of the Nashua Valley as seen in the unequal heights of its eastern and western rims, and the fact that

FIG. 1.

the Nashua River closely follows the base of the lower eastern ridge, is best explained by its longitudinal relation to the eastern or seaward slope of the Wachusett-Watatic mountain range or height of land.

The plutonic rocks of the eastern ridge include both basic and acidic types, the latter largely predominating. The basic rocks are

various phases (mostly secondary) of what might originally, perhaps, have been called diorite, and it is still convenient to use that designation, although through the combined influence of dynamical and chemical processes, chiefly shearing and chloritization, the rock has been largely metamorphosed to more or less typical chlorite and biotite schists. The acidic rocks are different types of granite — chiefly a very coarsely porphyritic biotite granite and an unusually well characterized muscovite granite; and the latter often assumes, where penetrating the schist, a distinct pegmatitic phase.

Although my study of the hard rocks covers, in a general way, the entire valley, close and detailed observations have been confined to the vicinity of the main dam and the tunnel, or the area represented by the accompanying map (Figure 1). But even in this limited tract most of the rock types indicated above — both sedimentary and plutonic — are well developed; and the main purpose of this paper, as already indicated, is to place on record the facts brought to light, often only temporarily, by the engineering operations.

My studies have not led to any definite conclusion concerning the geological age of these rocks. Both the sedimentary and plutonic types bear the characters of a high antiquity; and a comparison with the formations of the Boston, Norfolk, and Narragansett Basins makes me reluctant to accept the suggestion of the highly carbonaceous and even coaly or graphitic character of a small part of the sediments that they are Carboniferous. The sedimentary rocks are undoubtedly older than the plutonics, by which they are freely intersected; and the coarsely porphyritic structure of one granite and the muscovitic character of the other plainly suggest their formation at a great depth, in a truly abyssal zone. Except that they exhibit a more pronounced regional or general metamorphism, the sediments are not unlike the Cambrian strata of the Boston Basin; and that we have here an originally deeper portion of the Cambrian complex of Eastern Massachusetts appears, on the whole, the best provisional correlation.

Distribution, Characters, and General Relations of the Rocks.

In the vicinity of Clinton, and especially on the line of the tunnel, the geological structure of the eastern ridge of the Nashua Valley is rather more complex and interesting than at almost any other point;

and, regarded simply from the point of view of the light which their construction might throw upon the geology of the region, the dam and tunnel (and the same is true of the dikes) could hardly have been more advantageously located. Even the fact that the tunnel, in its southeasterly course, gives an oblique section of the ridge, causes it to pierce a greater variety of rocks and contribute more to the elucidation of the geological structure than would otherwise be the case.

The map is a graphic summary of the main facts. It shows (1) that the great series of argillaceous and siliceous sediments — argillites. phyllites, schists, and quartzite — is divided, approximately parallel with the strike, by two dike-like bands of porphyritic granite, one on either side of the river, the erosion of the intervening narrow band of relatively soft and yielding sediments having determined the gorge-like character of the valley of the modern Nashua in the vicinity of Clinton; (2) that the more eastern band of porphyritic granite is bordered on the east by a large compact body of the dioritic rock; and (3) that both the porphyritic granite and the diorite appear to end southward against a great boss of the muscovite granite.

Sedimentary Rocks. — From west to east — from the vicinity of the North Dike to West Berlin — the sediments present the following diversified section, the differences being partly original and partly secondary, the results of unequal metamorphism. West of Burdette Hill, on which the Clinton reservoir stands, in the North Dike area, the prevailing rock, as indicated by the natural ledges, and more especially by the numerous borings, is a soft and fissile light gray to dark gray, and even black argillite or phyllite. The variation in color is undoubtedly due in part to unequal surface oxidation, but in part, also, to original differences in the proportions of carbonaceous matter. The black layers, especially, are commonly more or less pyritiferous; and the rock is in general highly contorted and wrinkled, as may be well seen in the ledges west of the Catholic Cemetery. On the summits of Burdette Hill and Cedar Hill, on which the main part of Clinton is built, near the western band of porphyritic granite, the phyllite is in part more siliceous, and grades into true quartzite, of which there are some heavy intercalated beds.

The narrow band of sedimentary rocks separating the two bands of porphyritic granite is in part true mica schist along its eastern border, and embraces some typical quartzite, as may be well seen in the ledges near the bend of the river, half a mile south of the main dam. It is

for the most part, however, especially as revealed by the tunnel and the cores of the diamond drill borings, either gray, distinctly argillaceous, and rather firm and massive (a true phyllite), or black, highly carbonaceous (coaly and graphitic), semi-crushed, crumbling, and fissile. The total breadth of this belt in the vicinity of the tunnel and dam is nearly 900 feet, and the best general view appears to be that the crumpled carbonaceous beds mark the axis of an unsymmetrical syncline, the limbs of which have been largely cut away by the great dikes of granite. The only natural exposures of the highly carbonaceous beds are in the east bank of the river, opposite the Lancaster Mills.

The diorite area is bordered on the east by a rather coarse and gritty, hard and massive schist. The characters of this rock mark it very plainly as a metamorphic sandstone, and at some points it is now more properly a micaceous quartzite than a true schist. In structure it is almost as massive as the diorite; but it lacks the prevailing green (chloritic) color of the latter rock, and the two rocks are in general readily distinguished. In the vicinity of the tunnel the gritty schist has a general strike south, 45° to 60° east, or nearly parallel with the tunnel; while the dip is throughout high to the northeast. Hence, although the tunnel runs for almost exactly a thousand feet in this rock, no great thickness is indicated.

Immediately southeast of shaft No. 3 of the tunnel, the gritty schist changes rapidly, but not abruptly, to a much finer grained, softer, and more distinctly bedded rock, having the same strike and dip, and varying in character between an argillaceous or slaty mica schist and a micaceous slate. It is often thin bedded or shaly, but remarkably free from contortions or wrinkles, and rarely pyritiferous or carbonaceous. With the exception of about 200 feet of muscovite granite, the tunnel is in this slaty schist practically all the way from shaft 3 to shaft 4, or fully 2,100 feet; but most of the way the tunnel is approximately parallel with the strike, and, as before, only a moderate thickness is indicated. Near shaft 4 the schist resumes its normal north-northeast strike, with a westerly dip of 80°–90°, mostly about 85°, and holds this attitude to the eastern end of the tunnel. Throughout this distance of about 2,200 feet it is highly metamorphic —a true schist; and yet, as the cut on the Central Massachusetts Railroad clearly shows, it is in part of a highly graphitic and pyritiferous character.

The abnormal strike of the schists on the line of the tunnel between the diorite and shaft 4, or in the angle between the diorite on the north and the muscovite granite on the south, will be more fully considered in a later section. Farther north, on the direct road from Clinton to West Berlin, the strike is normal across the entire section east of the diorite.

Porphyritic Granite.—The western band of porphyritic granite first appears on the north in the ledges on the railroad north of the river and northeast of Clinton. It forms the abrupt eastern slope of Cedar Hill, on which Clinton stands, and of the col, or ridge, connecting this hill with Burdette Hill, on which the Clinton reservoir is situated. On the line of Chestnut Street the granite appears to expand abruptly, crossing the river, and having thus afforded a foundation for the dam of the Lancaster Mills. In Burdette Hill the granite widens rapidly, cutting obliquely across the phyllites and quartzites on the west, and attaining a breadth on the line of the main dam of about 2,000 feet. South of this hill the granite sinks beneath a broken plain of modified drift. But the North Dike borings prove that it is not interrupted. It appears in conspicuous ledges along the southern base of the plain, and again rather obscurely on Cunningham Brook, west of the old brick yard.

The granite of this belt is normally very coarsely and profusely porphyritic, being in large part crowded with feldspar phenocrysts from 1 to 3 inches long; but toward the margins of the belt the phenocrysts become elongated, broken, and indistinct, and the porphyritic structure gradually fades out with or without the development of a more or less pronounced laminated or gneissic structure. The gneissoid character is, perhaps, most clearly shown in the ledges along the west bank of the river in the vicinity of the main dam.

The relations of this belt of granite to the inclosing sedimentary rocks are most satisfactorily exhibited on the ridge between Cedar and Burdette Hills, in the ledges between Chestnut and Grove Streets. The granite, which is here devoid of gneissic structure, and rather fine grained, cuts the metamorphic slate and quartzite in every direction; and for a breadth of 50 feet or so the granite is, at some points, crowded with large and small angular fragments of the hard and massive sediments. The eastern contact, as disclosed by the borings on the site of the main dam, will be described in a later section.

The eastern band of porphyritic granite begins on the southwest,

near the Central Massachusetts Railroad, and forms the crest of the main ridge northward far beyond the limits of the map. Carvill Hill, immediately south of the line of the tunnel, affords a good surface section of this belt, its width here being about 2,000 feet. Between the tunnel and the Acre (an eastern suburb of Clinton) the western border of the granite is quite plainly broken, as if by a fault, which might be regarded as accounting also for the corresponding break noted in the western belt on the line of Chestnut Street (see map). Midway between the Acre and Bolton Station, and immediately north of the station, small quarries have been opened in the granite, displaying to good advantage its massive structure and its coarsely porphyritic texture, which is even more pronounced than in the western belt. At the Acre, on the northwest side of the road to Bolton Station, the contact of the granite and schist is exposed, and a little farther northeast on the other side of the road is an outcrop of massive gray slate, which is probably an inclusion in the granite. The contact is also nearly but not quite exposed on the east side of Boylston Street about a quarter of a mile south of the tunnel. On the southeast side of Carvill Hill the granite and diorite are seen near each other, but not in contact.

Everywhere near its contact, alike with the schist on the west and the diorite on the east, the granite of this belt is non-porphyritic and distinctly gneissoid. The lamination, which is invariably parallel with the contact, is, near the contact, often extremely fine and perfect. But within a few yards from the contact, as a rule, we pass gradually to the normal coarsely porphyritic granite. The most complete and satisfactory surface section of this great dike, as previously noted, is afforded by Carvill Hill, and especially by its abrupt southwestern slope. The gneissic structure is plainly marked throughout the entire breadth of the granite, especially by the lenticular forms of the quartz, and the usually parallel or approximately parallel orientation of the great feldspar phenocrysts. Through the western middle portion of the belt the normal granitic structure is best preserved; but advancing toward the schist, and more especially toward the diorite, the feldspars show distortion by stretching and cracking, which increases slowly at first, and then more rapidly until they finally become. like the quartz, mere strings. The origin or genetic significance of this interesting structure will be considered in a later section.

Diorite. — Although the distribution of the outcrops of this rock

is favorable to its occurrence in one large compact area, the facts are, perhaps, sufficiently meager to permit other interpretations. On the line of the tunnel, however, the diorite is unquestionably continuous for a breadth of 2,200 feet from the porphyritic granite on the northwest to the gritty schist on the southeast. The diversified aspects of this rock resulting from a varying combination of metamorphic influences have been noted. At some points it appears to be still a fairly normal diorite, composed of plagioclase and hornblende; and exhibiting at times an original flow structure. But in the main the original constituents, and especially the hornblende, have given way to secondary species, among which chlorite and biotite are most conspicuous. The diorite is also, even in its most altered forms, commonly and sometimes highly pyritiferous; and the secondary character of the pyrite is plainly indicated by the fact that its bright unaltered crystals appear to be especially characteristic of the most altered or more thoroughly chloritized portions of the diorite.

The diorite is, throughout, more or less distinctly foliated or schistose in structure, and in fairly definite directions conforming with the bordering granite and schist. Unlike the granite, the foliation is not confined to nor specially more marked in the marginal portions of the formation; and there seems to be no reason to doubt that it is a secondary feature of the diorite, and the product of dynamic metamorphism; although the question might be raised as to whether the pressure, in its turn, may not in part, at least, have originated in the chloritization and general hydration of the rock.

Concerning the relations of the diorite to the sedimentary rocks, the evidence is very scanty. In fact, I have observed no facts bearing directly upon this problem except such as were disclosed by the tunnel, and to be noted later; but these it may be stated have appeared to be sufficient to show that the diorite is younger at least than the gritty schist. The relations of the diorite to the porphyritic granite are less obscure. At the northern end of the belt, north of the direct road from Clinton to West Berlin, the granite clearly cuts the diorite in many irregular and branching dikelets, and incloses angular fragments of the diorite of all sizes up to 50 feet or more in diameter; and similar facts were brought to light by the tunnel. In several of the ledges to be crossed and covered by the south dike the diorite is intersected by dikelets of granite. The large ledge or group of ledges east of the dike between the highway and the Central Massachusetts

Railroad is of particular interest in this connection. The rock is chiefly fine gneissoid granite, but along the north side especially there is considerable dark hornblendic and distinctly laminated diorite. The relations of the two rocks are very clear. The granite dikelets cut the diorite parallel to the lamination, and elongated pieces and slabs of the diorite are inclosed in the granite parallel to the gneissic structure of the latter rock. The lamination of the two rocks is thus substantially conformable, being approximately vertical, with east-west trend. Where most closely involved with the diorite, the porphyritic structure of the granite is commonly wanting; and the natural ledges, especially north of Berlin Street, afford strong indications of a blending of the granite and diorite. There seems, in fact, to be little reason to doubt that these two rocks are successive products of one and the same original magma, formed as usual in the order of decreasing basicity; and the diorite masses, it is probable, are, to some extent, original segregations from the granite magma.

Muscovite Granite. — Southward, as the map shows, this type appears to take the place of both the porphyritic granite and the diorite; and within the limits of the map it forms two prominent hills — Snake Hill and Mile Hill. The outlines of this area are at no point sharply defined in surface exposures; but that its northern border follows closely the contours of the hills is reasonably certain, and definitely proved for the northeast side of Snake Hill by the tunnel.

In lithological character this is the most uniform rock of the entire district — a rather coarsely crystalline one-mica granite, and that mica a silvery muscovite. The gneissoid structure so characteristic of the marginal portions of the porphyritic granite has been observed only on the eastern border of the muscovite granite; but it is here remarkably perfect. On the Central Massachusetts Railroad, immediately east of the brook which winds around Snake Hill, is a rock cutting over 600 feet long in a beautifully gneissoid phase of the muscovite granite. The lamination crosses the railroad very obliquely, striking northeast-southwest, and dipping northwest 45° to 80°, but mainly 45° to 60°. The gneissoid structure, which is in the main very fine and regular, is not due to any appreciable degree to the parallel orientation of the muscovite; but chiefly, as in the porphyritic granite, to the drawing out of the quartz and feldspar. Quite marked slickenside surfaces coincide with the foliation. The foliation

becomes less distinct westward, and west of the brook is another cut between 100 and 200 feet long in which the structure gradually dies out, the gneiss fading into the normal muscovite granite. The tunnel supplements this exceptionally good surface exposure by showing that this highly foliated granite is closely and conformably bordered on the east by the schist; and that the structural relations are the same, therefore, as with the gneissoid phase of the porphyritic granite.

That the muscovite granite is eruptive through the schist is still more conclusively shown by the irregular, isolated masses of schist inclosed in the granite over the summit of Mile Hill. These are to be regarded as mere remnants of a once continuous covering of schist over the batholite; and the fact that they retain the normal dip and strike, with the bedding of the schist abutting squarely downward against the granite, is a plain indication that this great body of granite, like a true batholite, has made room for itself, and hence must in part, at least, have been formed, by melting and absorbing large volumes of the schist.

Concerning the relations of the muscovite granite to the porphyritic granite the evidence is not so clear. Following the analogy of the essentially similar rocks of New Hampshire, the muscovite granite is probably the general equivalent of the Concord granite and younger than the porphyritic granite, in which case it must also be younger than the diorite. In this connection it may be noted that in the porphyritic granite are occasional dikes up to 10 feet or more in width, of a fine and even-grained granite which might, perhaps, be correlated with the muscovite granite, but the micaceous element has not a distinct macroscopic development, and it appears best on the whole to regard it as a later non-micaceous, as well as a non-porphyritic phase of the same magma as the porphyritic granite.

Structural Details of the Site of the Wachusett Dam.

The general topography of the dam site can be gathered from the accompanying photographic illustrations. Figure 2 shows the river as it appeared in 1895, before the deforesting of its banks, with the drilling apparatus at work upon rafts, and the till-clad eastern slope of carbonaceous phyllite. Figure 3 is a view directly across the river from a point well up on the eastern slope, from which the surface soil has been removed, and showing the coffer-dam which now turns the

FIG. 2. — SITE OF THE WACHUSETT DAM, LOOKING SOUTHWEST (1895).

FIG. 3. — SITE OF THE WACHUSETT DAM, LOOKING WEST (1898).

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FIG. 4. — NASHUA RIVER, LOOKING SOUTH TOWARD THE SITE OF THE WACHUSETT DAM.

water of the river into the tunnel, and the abrupt western granite slope, made still more abrupt by a heavy bench of modified drift, and surmounted by the bold ledges of coarsely porphyritic granite forming the southern brow of Burdette Hill. Figure 4 is a view looking south or up stream toward the site of the dam in the distance, giving a general profile of the valley at that point, and showing the normal flood-plain of the river as laid bare by drawing off the water of the Lancaster Mill pond. The normal elevation of the surface of the river, as shown in Figure 2 and in the following sections, is 288.6 feet above low tide. The height of the bench or terrace of modified drift shown in Figure 3, and less distinctly on the right side of Figure 4, is about 390 feet above the same datum. This plain marks the principal level of the glacial lake of the Nashua Valley. Extending southward from it, and forming the west bank of the river above the coffer-dam, is a beautiful esker, which is shown in several of the sections, one of the diamond drill borings having been located on its crest. The elevation of the summit of Burdette Hill is about 530 feet, and of the crest of the eastern ridge above Boylston Street, 480 feet.

The borings, some 500 in number, made partly with the diamond drill but chiefly with the wash drill, on the site of the Wachusett Dam, and covering the entire breadth of the river and its immediately inclosing slopes for a distance up and down stream of nearly 300 feet, have disclosed in detail and with a high degree of accuracy the character and structure of the bed-rocks, the form of the bed-rock surface, and the depth and character of the superficial deposits or drift. I have made a careful study of the thousands of samples from the borings and of the accompanying notes, and have endeavored to correlate and interpret the borings geologically. The chief results of this study are given in the following sections, selected from a more complete series, all of which were drawn before the draining of the Lancaster Mill pond and the building of the coffer-dam.

The channel, or original bed of the river before the construction of the dam at the Lancaster Mills, lies under the west side of the river, the mean depth of water here being about 20 feet. To the east of this lies what was formerly the flood-plain of the river under 10 to 12 feet of water. Except at a few points on the slope above the west side of the river, the bed-rock is nowhere exposed, but is buried under a varying depth of drift — till on the eastern slope, and modified drift (sand and gravel) under the river and on the western slope. The

depth of drift under the river is considerable — 20 to 60 feet — and clearly fills a well-defined gorge between a sloping wall of metamorphic slate or phyllite on the east, and an abrupt wall of granite on the west; and the channel of the modern river is shown by the profiles to be directly over this granite escarpment, which varies in height from 20 to nearly 50 feet. The deepest part of the gorge is at the foot of this escarpment and on the contact between the granite and slate.

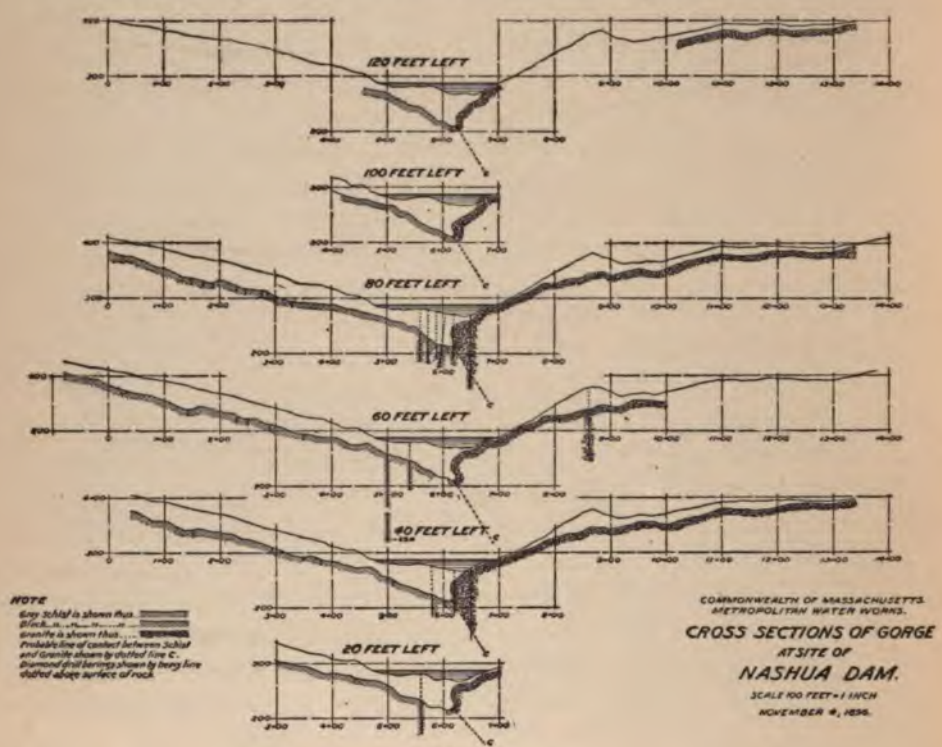

FIG. 5.

The slate or phyllite is chiefly the gray variety — a distinctly argillaceous, firm and massive rock. The diamond drill cores show that the stratification is obscure, being marked chiefly by occasional slickenside or shear planes, and the rock is rarely distinctly fissile or schistose except for a slight depth below the weathered surface. It is normally slightly pyritiferous and calcareous, and minute veinlets of quartz and calcite often form a complete network in the rock, increasing its massive character. The solid and massive structure of this normal slate is seen in the fact that in the diamond drill borings it cores nearly as well as the granite. Two principal variations from this type have been

noted. First, it becomes to a limited extent more siliceous, and passes into a slaty quartzite of flinty hardness. Second, it becomes distinctly and even highly carbonaceous, the carbon assuming, as previously noted, both coaly and graphitic forms, and making the rock black, slippery, and tender.

The borings show that the contact between the granite and schist is an approximately straight line, extending parallel with the axis of

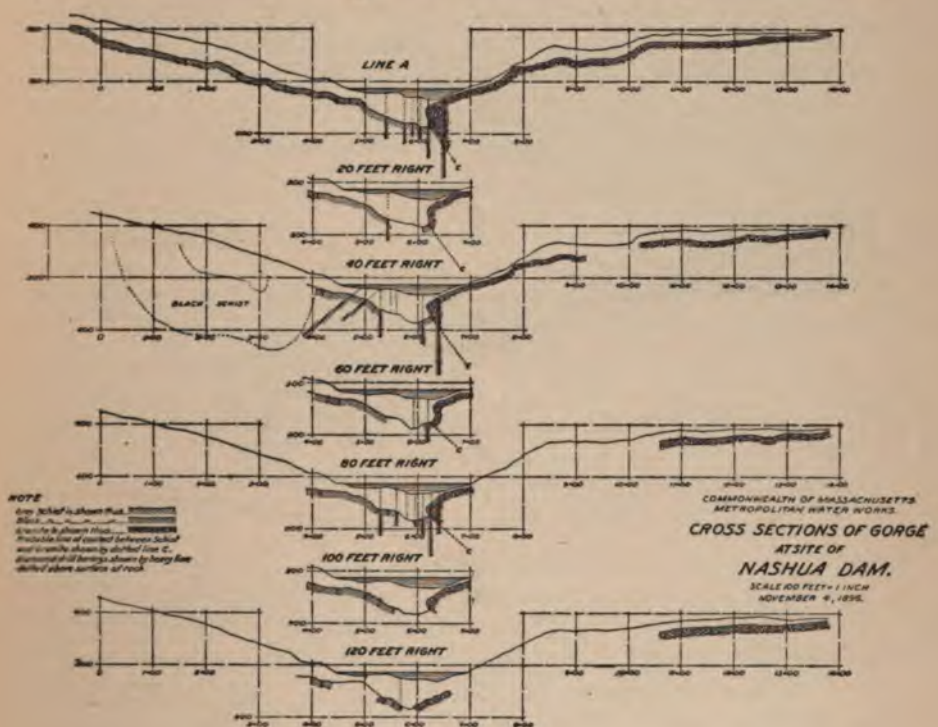

FIG. 6.

the river from about 6 + 20, 80 R, to 6 + 20, 80 L. (*C.* Figures 5, 6, 7, 8, and 9.) The diamond drill borings have also shown that the granite overlies the schist, nine different holes having passed through granite bed-rock into underlying slate, and in no case has granite been found below slate. This, together with the fact that the schist is reached at a greater depth in the more westerly holes, proves that the contact has a westerly dip. Fortunately, on each of four different profiles or cross-section lines — 80 R, center (A), 40 L, 80 L — two or more holes have passed through the granite into the schist, thus affording the data necessary to determine accurately the dip of the

contact. This is found to be in the main quite regular, all the determinations falling between 40° and 60°, and all but one (40 R) between 55° and 60°. A careful examination of all the cores near the line of contact shows that this is also the normal dip of the slate, the granite having forced its way up through the slate parallel with the bedding of the latter, an original plane of weakness having been determined here by a thin bed of the highly carbonaceous (coaly and graphitic) slate with streaks and partings of the gray slate. The more easterly borings, and especially the tunnel, showed, however, great variations in the dip of the schist, the bedding being almost horizontal at some points and nearly vertical at others, but always to the west. These marked variations of the dip are found to occur chiefly in the soft,

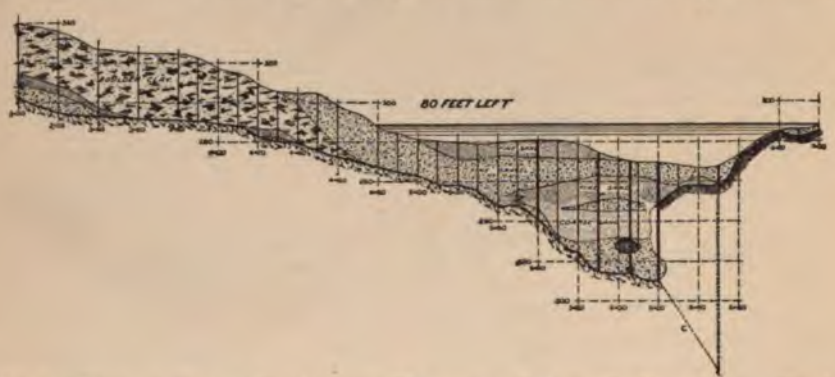

FIG. 7. — PROFILE OF THE SITE OF THE WACHUSETT DAM AT 80 FEET LEFT. (South.)

carbonaceous schist, which has yielded most readily to the bending and shearing stresses to which the formation has evidently been subjected.

In the ledges along the west bank of the river, the lamination or foliation of the granite is seen to have the same westerly dip as the contact of the granite and schist. This is clearly an igneous contact, and not due principally to faulting. This is proved by the facts that the granite incloses fragments of the slate, that it is shown by several of the cores to be firmly welded to the slate, and that it shows the normal gradation in texture, being usually very fine-grained next the slate, becoming coarser away from it, and coarsely porphyritic at a moderate distance.

The stream which excavated the buried gorge over which the Nashua now flows evidently tended to follow down the sloping contact of the granite and slate, the contact layer of carbonaceous slate offering a special inducement for it to do so. The geological condi-

tions were thus extremely favorable to the undercutting of the granite, and the development of a very unsymmetrical profile, a gently sloping eastern wall of schist, and an abrupt or overhanging western wall of granite. The precipitous character of the granite wall is proved by the very unequal depths of the bed-rock surface in closely adjacent

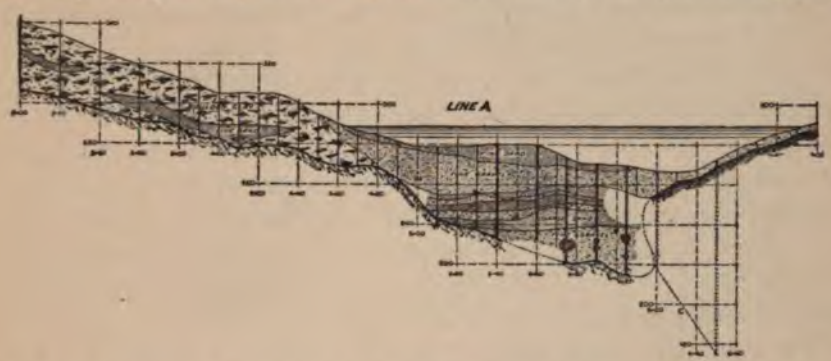

FIG. 8. — PROFILE OF THE SITE OF THE WACHUSETT DAM AT LINE *A*. (Center.)

borings on opposite sides of this line, and also by the character of the cores from several of the diamond drill holes in the granite, especially center line 6 + 20, 40 L 6 + 20, and 80 L 6 + 20. In these cases the drill penetrated the granite for 36.5, 44.4, and 27.0 feet, respectively, and yet through almost these entire thicknesses the granite is

FIG. 9. — PROFILE OF THE SITE OF THE WACHUSETT DAM AT 80 FEET RIGHT. (North.)

rusty and weathered, especially along the joint cracks, indicating quite plainly that the holes were bored only a few feet back from the weathered face of a cliff or very abrupt slope.

Doubtless the most surprising fact developed by the diamond drill borings is the occurrence of gravel below the granite in a number of instances. Several of these have proved, when carefully plotted on the sections, to be probable bowlders. This interpretation is possibly applicable at 60 R 6 + 20, and 80 R 6 + 25, the alternative hypothe-

ses being expressed in the sections, but not at 80 L 6 + 20, where the drill passed through 27 feet of granite, the upper surface of which agrees closely with all the other profiles, since it would require us to imagine a long narrow bowlder poised on its end. The most natural explanation of this phenomenon seems to be this: The stream which formerly occupied and made this gorge, working down along the contact of the granite and schist, and acting laterally as well as vertically on the bed-rock, has undercut the granite to a moderate distance, several feet or yards, back from the face of the granite wall. Under the circumstances it would be very surprising if some undercutting had not occurred. That the undercutting is not very extensive is indicated by the failure to find the gravel in 40 L 6 + 20, although this boring crossed the level, and the geological position (contact of granite and slate) at which the gravel occurs in the other borings. The boring at 6 + 20 center line (*A*) apparently just misses an undercut at the base of the cliff, the 3-inch seam of sand at elevation 225 probably filling a widened joint crack extending a few inches back from the face of the ledge. The undercutting of the cliff appears so natural and almost inevitable that it has been indicated in some degree on all the sections.

The undercutting of the granite cliff, together with the joint structure of the granite, presents conditions extremely favorable to the detachment of large masses of granite; and several such undoubted bowlders are shown in the sections, the largest being 15 to 20 feet thick, and 20 to 30 feet long. The wash drill borings have isolated these masses, and the diamond drill has passed through them into underlying gravel, fully demonstrating that they are bowlders. The horizontal continuity of the longer ones might seem open to question; but it is required by the consideration that the horizontal diameter would naturally exceed the vertical.

A comparison of the sections shows that the granite cliff diminishes in height both northward and southward, holding its full or maximum height from about 40 right to 80 left, or 120 feet. The bowlders evidently diminish in size and number southward, and they are found wholly in a mass of gravel filling the bottom of the gorge. The upper surface of this bowlder-bearing gravel descends southward from about elevation 240 to 220. It is also very noticeable that the overlying deposit of modified drift, 30 to 50 feet in thickness, becomes finer southward, gravel greatly predominating in the northern sections and sand in the southern. Again the sections show that the bottom of

the gorge also slopes southward, the lowest level of the bed-rock surface definitely determined being 210 feet by the diamond drill boring at 80 left, 6 + 20. On line *A* the lowest point cannot fall much below 215, and on the line 80 right 215 feet is quite certainly the minimum elevation. The gorge also becomes narrower and more gorge-like southward.

All these facts agree in indicating that this gorge must have been excavated and filled by southward-flowing currents, and hence not by the Nashua, which now flows through this valley in the opposite direction. The surface bed of fine sand, 5 to 10 feet thick, probably once extended across the valley; and the excavation of its channel in this material is the only geological work that can be credited to the Nashua River flowing along this line. Its failure to cut deeper into these loose deposits is explained by the fact that at the dam of the Lancaster Mills, half a mile below (northward), it flows over a ledge of granite. The general distribution of the outcrops in this part of the valley, and all the topographic features, are favorable to the view that the buried gorge dies out northward, and that from this amphitheater of abrupt and rocky slopes encircling the Lancaster Mills and mill pond, a similar buried gorge probably trends northward, the dam of the Lancaster Mills resting on the water parting or dividing ridge of the two glens.

It is interesting to note in this connection that in some of the North Dike borings, north of Sandy Pond, the bed-rock has been reached only at a depth or grade fully 100 feet lower than the lowest point on the dam site. This fact confirms in the most conclusive manner the view that the Nashua River is now out of its preglacial channel, which lies a mile to the west of the dam site, and flowing at a level nearly or quite 175 feet higher. In preglacial times a small tributary probably started from near the present site of the Lancaster Mills, and flowed first south and then west to join the Nashua near the present site of Sandy Pond. The drift deposits left by the great ice sheet so completely filled and blocked the main valley that the river was forced to flow up the valley of one of its tributaries, and over the divide into the valley of a northward-flowing tributary. This means that no higher bed-rock foundation for the dam could probably be found in the course of the Nashua River.

The sections on a scale of 100 feet show the general relations of the gorge to the valley, and give only the diamond drill borings, and the depths to which they have penetrated the bed-rock, the deepest hole, at 60 L 5 + 00, extending about 30 feet below sea level.

STRUCTURAL DETAILS OF THE WACHUSETT AQUEDUCT TUNNEL.[1]

Besides the thin layer of carbonaceous slate along the granite-slate contact, occasional streaks and limited patches of it occur in and blend with the normal gray slate, before we come to the great development of this rock on the east side of the valley indicated by the borings, and fully proved later by the excavation of the tunnel. Shaft 1 of the tunnel (1 + 85) is in the gray phyllites which are here obscurely bedded with many slickensides. Between the shaft and the river the borings show fully 100 feet of the black graphitic slate, and immediately east of the shaft the tunnel enters a very typical development of the same rock, in which it continues without interruption for nearly 200 feet. Between stations 3 + 70 and 4 + 40 more or less gray slate alternates with the black; but beyond this the black slate is practically continuous for 200 feet more, and then gradually gives way to the gray phyllites. The black slate is throughout graphitic, and much affected by slickensides; and it is often, also, more or less tender and coaly. Pyrite is sometimes a conspicuous constituent, but as a rule it occurs sparingly or is wholly wanting.

The dip of the black slate is always to the northwest, but often indistinct, owing to the broken and chaotic condition of the formation. Starting from the shaft, it is low (30° or less) to 2 + 60, then high (70° or more) to 4 + 60, then low again (40° or less) to 5 + 60, and then gradually steepens to 80° and more. That the low dips between the shaft and 2 + 60 mark a synclinal axis, as indicated on the dam section for 40 R, is reasonably certain, especially in view of the fact that the deep, inclined diamond drill hole at 5 + 00, 40 R, although penetrating to 3 + 80 at grade 190, is wholly in the gray rock, except a small amount of black slate with quartzite near the top of the hole. This seems to show at least that the black slate does not dip down beneath the river, and the only alternative is to connect the two bands beneath the shaft. The sections of the dam site were drawn before the tunnel had passed through the black slate; but it now appears probable that the steeply dipping complex of black and gray slate between 2 + 60 and 4 + 60 marks a sharp anticline, followed on the

[1] Measurements in the tunnel, and the east-west measurements of the dam site run in opposite directions, and overlap somewhat, the starting point or station 0 + 00 for the tunnel being station 4 + 95 for the dam site, or about 125 feet east of the granite-slate contact, and near the east bank of the river.

east by a second syncline similar to the first. Although the advantageous position of the deep, inclined diamond drill holes was not fully foreseen, they are fully justified by the neat way in which, as it were, they head off the black slate, although it may be added that the vertical hole over 300 feet deep 100 feet south of this, at station 5 + 00 60 L, strongly corroborates the testimony of the inclined holes. From what precedes, it appears that all the observed facts of the dam and tunnel sections find a consistent and natural explanation in the assumption that one principal bed of carbonaceous slate is involved, with the underlying and overlying gray slate or phyllite in which are occasional carbonaceous patches and layers, in a closed and double synclinal fold, with its axial planes dipping steeply to the northwest.

The last trace of graphitic slate was observed in the tunnel at 6 + 80. Beyond that is a distinctly bedded, typical, gray sericite schist with quartzose bands and passing into a true mica schist as it approaches the granite. The dip is northwest 60°–90°, and undulating, or in part minutely wavy. At 7 + 58, where the dip is northwest 80° +, a very marked crushed zone 6 to 8 inches wide and parallel with the bedding crosses the tunnel about at right angles. This is a very obvious fault between the schist and the finely foliated or schistose granite. This important contact is now concealed by brickwork. The hard and solid distinctly

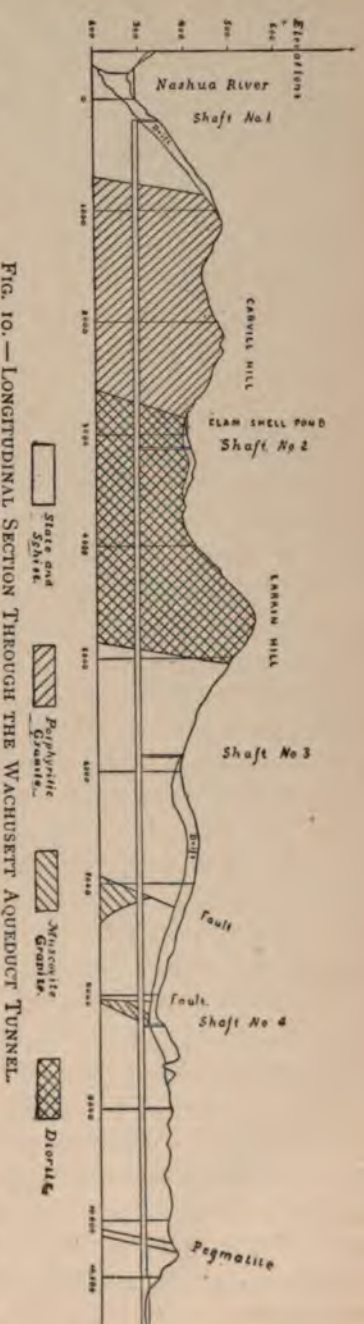

FIG. 10.—LONGITUDINAL SECTION THROUGH THE WACHUSETT AQUEDUCT TUNNEL.

and finely gneissoid granite, dipping northwest 80°–90°, and somewhat wavy, is continuous from 7 + 58 to 8 + 27. Between 8 + 27 and 8 + 45 the rock is a hard and massive but wavy mica schist, with the same dip as the granite, and firmly united to the granite on both sides in apparent igneous contacts. At 8 + 42 this inclusion of schist is broken by a strongly marked and very wet fault fissure which crosses the tunnel at right angles and hades with the dip. The schist shows much disturbance here, and is partly crushed. Irregular bunches of quartz occur in the fault, and also in the granite and schist between 8 + 10 and 8 + 30. Beyond 8 + 45 the laminated gneissoid structure of the granite, dipping northwest 70°–80°, becomes gradually less fine and distinct. Near 9 + 25 the porphyritic structure first attracts attention, and beyond 9 + 75 the normal coarsely porphyritic structure is well developed, except for a general parallelism of the phenocrysts, and aside from this, the rock is, as a rule, only coarsely and indistinctly laminated. At 9 + 60 a very marked and perfect shear zone and clay seam crosses the tunnel obliquely, and dips northwest 75°. It is 6 to 12 inches wide, perfectly plane and very wet — an ideal fault. Near station 10 + 10 another wet shear plane 1 to 4 inches wide crosses the tunnel obliquely and dips northwest 65°. At 10 + 82 a strong shear plane, open and wet, 4 to 12 inches wide and dipping northwest 75°, crosses the tunnel nearly at right angles. Another not so wide joins this obliquely, and a third crosses at 11 + 00 parallel with the first. Beyond 10 + 00 the granite is continuously very coarsely porphyritic; the gneissoid structure is indistinct or wanting, and prominent vertical dry joints cross the tunnel approximately at right angles every 5 to 10 feet for a long distance. Between 12 + 80 and 12 + 90 two of these joints are accompanied by clay seams and crushed zones. At 13 + 25 a mass of schist is inclosed in the granite. A strong and irregular clay seam and crushed zone crosses the tunnel at 14 + 00, dipping northwest about 60°. Through this part of the granite the gneissoid structure is marked chiefly by the parallel orientation of the great feldspar phenocrysts, which range from 1 to 5 inches in length. The high northwest dip diminishes rather gradually to 35° at 16 + 00. In the vicinity of 15 + 25 are several quartz veins 3 to 12 inches wide and 3 to 8 feet long, and approximately at right angles to the lamination of the granite. They are evidently segregated lenses filling cracks due to a stretching of the granite in the direction of its

lamination. At 16 + 25 a very wet seam or open joint crosses the tunnel, following the course of a large and irregular pegmatitic development of quartz, feldspar and chlorite (altered hornblende or biotite). Some masses of quartz are 1 to 2 feet in diameter, and the pegmatite blends with the inclosing granite. It forms one large irregular mass on the northwest wall 10 feet in diameter, and a vein 3 to 4 feet wide crosses the roof but does not reach the southwest side. The wet fissure dips northwest 45°, and on the southwest side of the tunnel takes the form of a crushed zone. At 17 + 55 to 65 is apparently another inclusion of fine and massive schist, which crosses the tunnel nearly at right angles as a layer 8 to 9 feet wide, and dipping northwest 50°–60°. The contacts are sharp and plain, and rather wet. Still other slabs of schist having the same dip occur in the granite near 18 + 00. At 22 + 10 a dike of fine granite cuts the porphyritic granite, and at 22 + 20 is a 3-feet vein of quartz dipping northwest 50°. The hanging wall of the vein shows movement, and is very wet. At 23 + 00 and 23 + 25 are inclusions of dark colored, massive schist, or possibly diorite. A more important body of schist — hard, quartzose, and very massive — extends from 24 + 13 to 24 + 37. The well-defined contacts dip northwest 45° to 70°, and are typically igneous, fragments of schist occurring in the granite and dikelets of granite in the schist; while the granite is non-porphyritic and finely gneissoid parallel with the contacts for a breadth of 5 feet. At 25 + 00 and 26 + 00 are inclosed masses of diorite, and at 26 + 10 is another mass of schist which extends to 26 + 20.

The coarsely porphyritic, massive and indistinctly gneissoid characters of the granite are practically uninterrupted for over 1,600 feet; but east of 26 + 00 the phenomena of the western border are repeated, and the porphyritic structure rapidly but gradually gives way to a fine and even foliation, the granite becoming at last almost indistinguishable from a true schist, as we near the contact with the diorite at 26 + 90. The dip is northwesterly, as before, but comparatively low, 30°–45°.

Between 24 + 30 and 25 + 30, but much more decidedly east of 26 + 30, the granite shows more or less decomposition, especially along prominent joint and shear planes, some of which are very wet. It is in part completely disintegrated and well advanced in kaolinization, recalling the rotten gneiss of the Hoosac Tunnel, and seeming to possess, like that, a special interest as an instance of deep-seated

decay dating in part, possibly, from preglacial times. In explanation of this phenomenon we may note that the granite is in general a very hard and rigid rock, and the joints, which are due to earthquake and other movements, are naturally more open than in the more yielding diorite and schists; and consequently this part of the tunnel, in the granite and below Clam Shell Pond, is extremely wet. This free and long continued circulation of surface waters through the granite is quite clearly the cause of the decomposition; and since it is probable that the decay will be somewhat accelerated by the more active circulation which the tunnel permits, a part of this ground has been lined with brickwork.

The contact of the granite and diorite, now concealed, crosses the floor of the tunnel near 26 + 80 and the roof near 27 + 00, dipping northwest about 30°. Although this is undoubtedly an igneous contact, due to the eruption of the granite through the diorite, movement has subsequently occurred along it, giving rise to a well-marked zone of crushing and shearing; and the passage of water through this broken material has caused more or less decomposition, especially of the granite.

Lithologically, the diorite is subject throughout to constant variations with the varying prominence of its secondary minerals — pyrite, biotite, chlorite, epidote, and calcite — the epidote and calcite occurring usually as distinct segregations and veinlets. East of the contact the diorite is indistinctly laminated or sheared parallel with the contact, northwest 30°–35°. At 27 + 30 is a strong shear plane and clay seam, and another at 27 + 80. Beyond 28 + 50 the rock becomes much more massive and solid, and so continues with occasional shear planes to shaft 2 (33 + 10).

For the first 600 feet east of shaft 2 the diorite is massive, and the lamination, where observable, dips northwest and north-northwest 45°–50°; while for a good part of the distance very regular joints hade (inclination to vertical) to the southeast 10°–15°. Between 35 + 70 and 90, a shear zone 6 to 12 inches wide dips northwest 45°, and at 36 + 00 is another. For about 250 feet beyond 37 + 30 the diorite is less solid and more affected by clay seams and crushed zones, and the principal joints dip north and north-northeast at high angles, the rock being completely sheeted by them at some points. The most conspicuous crushed zones are at 37 + 44, 37 + 80, and 39 + 60, dipping northwest as usual. Beyond this the diorite is somewhat quartzose

and very massive to 43 + 50, after which it is, in the main, strongly laminated and often shaly, the structure planes dipping north and north-northeast 70° to 85°, parallel with the diorite-schist contact, and so continues to the end.

The contact between the diorite and gritty schist is nearly vertical, and crosses the tunnel very obliquely, cutting the southwest wall at 48 + 80, and the northeast wall at 49 + 20; and in taking a general view of the structure of the diorite, no fact appears of greater significance than the conformity of the lamination (which must be, in the main at least, a secondary feature) with the diorite-granite contact in the western half of the belt, and with the diorite-schist contact in the eastern half of the belt. The chief evidence that the latter contact is igneous is found in the fact that the main contact is followed in the next hundred feet or so by several alternations of diorite and schist, suggesting dikes of diorite.

The massive and gritty schist presents few details of interest beyond what have been stated. In structure it varies continually from very massive to quite distinctly laminated or even shaly. The strike is usually approximately parallel to the tunnel (south 42° 30′ east) and the dip is northeast 60°–85°. Occasionally the strike varies to south 60° east, and in the vicinity of shaft 3, to south 70° east. Irregular veins and lenses of quartz are of frequent occurrence. Many of the principal joints tend to conform in direction with the stratification, giving the rock a platy structure, and at several points slipping along these planes has developed more or less distinct crushed or sheeted zones. One of these, about 2 feet wide, occurs between 51 + 50, and 51 + 80; and another 3 feet wide was noted at 58 + 35, near the shaft.

Beyond shaft 3 (58 + 55) the gritty schist gives way rapidly but not abruptly to the slaty schist, which is continuous to the muscovite granite at 70 + 60. This rock, which is usually free from pyrite, and rarely contains more than a trace, is very distinctly stratified; and the rock cleaves or separates very readily along the bedding planes into layers from an inch to several inches or a foot or more in thickness (slaty structure); but very frequently also it subdivides or splits up almost indefinitely, becoming highly fissile (shaly structure). These bedding planes are invariably very smooth, and even slippery, and are commonly striated or grooved in a definite direction, showing very plainly that differential movement or slipping of the beds has oc-

curred; and this movement, where most severe, has developed numerous crushed zones and clay seams. Similar movements, resulting in the smoothing, fluting or comminution of the rock, have occurred along the many prominent joint planes, of which there are usually two well-defined systems, one often vertical and the other inclined, and both intersecting the bedding planes. The strike of the bedding is approximately parallel to the line of the tunnel, usually bearing north of the tunnel from 0° to 20°, and the dip is steadily to the north-northeast, varying from 60° to 80°, but usually near 70°.

At 67 + 70 the strike is suddenly deflected to the north 20°, and beyond this the rock is much contorted and broken for 50 feet or more. Between 69 + 00 and 69 + 70, three strongly marked clay seams cross the tunnel in the bedding planes. They are very obvious faults. Between 70 + 40, and 70 + 50 the strike suddenly shifts again, to north 80° east, and from this point to the beginning of the muscovite granite, at 70 + 60, the rock is highly contorted and crushed.

The contact of the schist and granite crosses the tunnel at right angles and dips northwest 70°. It is distinctly igneous, the two rocks being firmly welded together; but near the granite the schist is much comminuted and very shaly, and shows two strong clay seams parallel with the contact, one about a foot from the granite, and the other 6 to 8 feet from the granite. It is very evident that this contact, although originally igneous, is now an important fault, the magnitude of the slip being indicated by the effect upon the dip and strike of the schist, and the sharp up-turning of the beds proves that the schist is on the down-throw side of the fault. The granite extends for about 105 feet along the southwest side of the tunnel, but for only 50 feet along the northeast side, the eastern contact of granite and schist cutting the tunnel very obliquely. The granite is evidently a jutting angle of the boss of Snake Hill, as the map indicates; and doubtless the tunnel would have missed it altogether had it been run a few yards farther north. The eastern contact appears to be essentially similar in history and character to the first — an igneous contact modified by a fault, but dipping northeast 80° instead of northwest 70°. The schist is in beds 2 to 12 inches thick, except near the contact with the granite, where it is very shaly for 2 to 3 feet, and more or less for 5 feet. The granite is normal throughout, the marginal gneissoid phase not being developed here.

East of the granite the micaceous slate continues essentially un-

changed, except that, the tunnel being here nearer the surface, a large proportion of the rock is distinctly oxidized or rusty (weathered) and tender or rotten in texture. The strike is in the main closely parallel with the tunnel, but varies both to the north and south of this line, as if the granite were near by on the south, and the dip is northeast 70° to nearly 90°. Crushed zones and clay seams of sensible thickness are not a prominent feature, but practically every bedding plane and every joint plane is a thin clay seam. They are remarkably smooth, striated in a definite direction, usually northwest at angles of 30° to 45° with the vertical, proving slipping, and coated with an impalpable clay due to this movement. At 73 + 10 a clay seam 2 to 8 inches wide dips east 15°.

At 80 + 62 an important and nearly vertical fault crosses the tunnel nearly at right angles. It is a very wet open fissure, and its great structural value is found in the fact that it marks a very abrupt general change in the strike of the schist. Northwest of the fault the strike is, as usual, parallel with the tunnel and the dip north 85°–90°, and the strata maintain this attitude right up to the fissure, while in the southeast wall of the fault the strike is parallel with the fissure (north-northeast) and the dip northwest 70°. On one side of this sharp line the strike follows the tunnel closely for 3,000 feet, and on the other side it is approximately at right angles to the tunnel for 2,500 feet and probably much farther.

The tunnel begins now to cross the strata, and they exhibit greater variety in consequence, layers of slaty quartzite first relieving the monotony of the series. At 81 + 60 the dip has increased to northwest 85°, and at 82 + 00 we come to the contact of the schist and the highly and finely laminated (gneissoid) muscovite granite. The contact is parallel with the foliation of the granite and bedding of the schist, and dips northwest 75°. The granite, still holding its gneissoid structure, continues to shaft 4 (83 + 12), where, near the bottom of the shaft, it is conformably underlain by the schist, dipping northwest 65°–70°. As previously noted, this narrow band of gneissoid granite is clearly a northward extension of that so well exposed on the Central Massachusetts Railroad, a great dike or branch from the parent boss. The brick lining of the tunnel is continuous from shaft 3 to shaft 4.

East of shaft 4 and the muscovite granite, the schist begins to be pyritiferous and graphitic. The graphitic character, with marked variations and slight interruptions, continues for 800 feet to 91 + 10, the

dip continuing steadily northwest 80°–85°. As the graphitic character fades out, a coarse biotite becomes more or less prominent in parts of the schist, these alternating with both quartzose and pyritiferous bands. Beyond 92 + 50 the schist becomes more solid and massive, and is rarely graphitic or decidedly pyritiferous; but it is commonly quartzose or biotitic. Between 93 + 85 and 93 + 90, a strongly marked crushed zone and clay seam parallel with the bedding, and 1 to 5 feet wide, crosses the tunnel. A vein of quartz 6 to 18 inches wide follows the south wall from 94 + 10 to 94 + 50. Beyond this, pyrite again becomes a prominent character in much of the schist, with some pyrrhotite and chalcopyrite, and continues to the end of the tunnel. East of 97 + 00 the schist again becomes somewhat graphitic as well as pyritiferous. At 97 + 35 is a strong and very wet clay seam. The 10 feet between 97 + 60 and 97 + 70 is about half quartz in large and small veins, the larger veins inclosing many angular fragments of the schist; and beyond this the schist is more or less veined with quartz and calcite to 98 + 00 and beyond. At 100 + 70 a crushed zone several feet wide crosses the tunnel; another at 102 + 70, and a clay seam at 103 + 90. At 100 + 80 the interbedded veins of pegmatite begin to appear, and the pegmatite is almost continuous from 101 + 00 to 101 + 50, appearing again at 103 + 10, and 103 + 90 to 104 + 00. At 101 + 40 a massive blue mineral thought to be fluorite adds variety and interest to the composition of the pegmatite. For the last 1,500 feet of the tunnel, and more or less all through the pyritiferous schists, the walls and roof were stained at intervals by bright orange-colored deposits of ferric hydrate (limonite) formed by infiltrating meteoric waters and indicating active oxidation of the pyrite. And for the last 250 feet, or as far as the conditions favored evaporation, the rock was whitened by an efflorescence of calcium and sodium sulphates, showing the potent influence of the oxidation products of the pyrite in decomposing the associated silicates. East of shaft 4 the dip is very constant, northwest 80°–90°.

General Conclusions.

In a general view of the geology of the tunnel, including also the dam site, two facts are especially prominent: (1) The normal strike (north-northeast to south-southwest) holds continuously west of the middle of the diorite, and east of station 80 + 62, while for the

intermediate distance of over 4,000 feet, following the line of the tunnel, the strike is transverse and nearly at right angles to the normal. (2) For the normal strike, all the important structure planes other than joints, including bedding planes, foliation and shear planes, crushed zones and faults, dip to the northwest, usually at high angles (30°–90°), while for the transverse strike the dip is constantly to the northeast, and always at high angles (60°–90°). The persistent northwesterly dip accompanying the normal strike is evidently a fact of great significance in its bearing upon the general structure of the Nashua Valley, but demanding for its full understanding and correlation a wider study than has been attempted here. As previously stated, the transverse strike appears to affect the formations for only a moderate distance northward from the muscovite granite; and it is evidently related to the sudden appearance of this boss athwart the dominant trend. The general structure is clearly such as would result from an important fault along the northern border of the muscovite granite with the downthrow to the north, and causing by its drag a sharp upward flexure of the schist and the diorite. Although not clearly expressed on the map, this great displacement is proposed provisionally as the best general interpretation of the structure. The faults so clearly and closely bordering the muscovite granite between 70 + 60 and 71 + 60 in the tunnel have precisely this influence upon the structure of the adjacent schist, and they are regarded merely as local phases or expressions of the main displacement.

Throughout the tunnel the joint structure is usually well developed, and commonly in two approximately rectangular systems which show a marked tendency to be normal to the shearing and bedding planes, suggesting that the joints should, perhaps, be regarded as tension cracks developed during the plication and shearing of the rocks. It is certainly noteworthy that in an area where the rocks are so thoroughly sheared, faulted, and jointed, dikes or any igneous intrusions of later date than the plutonics should be entirely wanting; but such appears to be the case.

That the lamination or foliation of the diorite is chiefly and of the granites partly a secondary structure due to shearing stresses originating in a transverse compression of the formations, is reasonably certain. The remarkably perfect marginal gneissic structure of the granites, on the other hand, is, in my opinion, best regarded as an original structure due to the drag of the stiffly viscous granite magma along

its walls during its intrusion into the schist and diorite. In fact, this structure appears to find a perfect explanation in the not unreasonable assumption that the magma continued to flow not only after the formation of the phenocrysts, but after the ground mass itself began to stiffen and harden. This explanation accounts equally well for the general, but often imperfect, parallelism of the phenocrysts with the walls throughout the entire thickness of the porphyritic granite, and for the fact that the gneissic structure is in both granites most strongly marked near the walls, and becomes rapidly less perfect away from the walls. The still plastic quartz was drawn out like half molten glass into thin sheets and lenses, while the feldspar phenocrysts were stretched, broken and dragged out, suffering by virtue of the high temperature and pressure in the presence of water plastic as well as clastic deformation.

Both the quartz and feldspar of the ground mass, but especially the former, show the fluidal elongation more or less throughout the granite. In short, the whole gneissic character of the granites, with the exception of certain shear planes, may be regarded as flow structure, sharply accentuated, as flow structure should be, along the borders of the granite. Even where most finely and perfectly developed, this true gneissic structure does not render the granite notably schistose or fissile, but it is still a firm, solid rock.

According to the alternative hypothesis, the gneissic structure is secondary, the product of compressive stresses and consequent shearing, or plastic flow, if the rocks were, as we may suppose, in the zone of flow. This view fails to explain the marginal localization of the more perfect phases of the structure; and furthermore, the true shearing, like close jointing, not only renders the rock fissile, but it is somewhat uniformly distributed through both the granite and diorite. Original flow structure is especially characteristic of acid magmas; while the granites being decidedly the most rigid of all the rocks of this region except the quartzites, and these are not generally foliated, should according to the compression hypothesis, be throughout of exceptionally massive structure. But in reality they are, marginally, as highly foliated as almost any of the schists, and much more so than a large part of the schist series.

DIESEL'S RATIONAL HEAT MOTOR.

By E. D. MEIER, C. E. and M. E.

Read February 23, 1899.

Many of my audience will, no doubt, feel that I am stating a truism when I preface my remarks by saying that all the power which man uses is derived, in a more or less direct manner, from the heat of the sun. For many centuries animal or muscular force, and the simplest applications of wind and water power, sufficed to fill the modest requirements of the human race. It is true that priestcraft, which seems to have been the earliest modification or check on the rule of might, did use direct heat as a force for performing some simple operations, such as the speaking or singing of hollow statues, or the moving of temple doors, all enveloped in mystery, partly because the authors themselves could not explain them, and partly because this mystery was a bulwark of defense against the crude force of the warrior. And somewhat later, the first engineer that we know of, Hero of Alexandria, did build and operate the first steam turbine.

But centuries passed again before even the wisest and most imaginative men began to appreciate the vast consequences and the great advantages which would follow the practical utilization of the direct force of heat. Even war, the delight, the sport, and the sole support of kings and nobles, was slow in utilizing the tremendous force of suddenly liberated heat. And then cannons and muskets had been used for nearly three centuries before any one thought of applying the tremendous energy of expanding gases to the useful arts; and when it was done the effects only were studied, no one even suspecting the cause. Towards the end of the seventeenth century we come upon a period of experimentation.

The Marquis of Worcester, in 1663, forced water to what was for the time an unprecedented height, about 40 feet, by the expansive force of steam, while Huyghens in 1680, and Papin in 1690, attempted

to produce motion and power through the explosive force of gunpowder, and again in 1698 Savery used steam in what we may consider the original pulsometer pump.

Nearly a full century passed before Watt, in 1769, succeeded in harnessing the expansive force of steam, and almost at the same time Street (in 1791) succeeded in moving an engine by exploding the vapor of turpentine in the cylinder. We see, then, that the beginnings of the steam engine and the internal combustion engine fall into about the same period. Neither of these experimenters and inventors recognized heat as being the primal potential energy which he was trying to utilize. Had this been done at that early period, it is more than likely that the vast industrial development of the nineteenth century, with all the myriad blessings it has conferred upon humanity, would have been retarded, or possibly even delayed for a number of decades. For if heat had been recognized as the prime mover, it is very probable that the bulk of the work of experimenting and invention would have been directed toward the internal combustion engine. But there was then no chance of success for this really more rational type. The steam engine with its many inherent defects and its wasteful cycle had to precede and break the way, just as the ox team of 1849 preceded the Pacific railways of 1865.

A clear knowledge of cause and effect would have compelled fair reasoners to decide that the heat should be produced at the very point where it is to be utilized. But neither materials, lubricants, tools, or skill were then available to harness this mighty force in its naked strength. Steam presented one great advantage over all competitors, that it could be used at very low pressures, such as the means at hand were sufficient and ample to contain and utilize. From the 8 pound pressures of the early Atlantic steamers, or of the wooden boilers of the Fairmount Water Works, to the 200 pounds and over of the present ocean greyhounds and the latest Leavitt pumping engine, is indeed a far cry; and this distance had to be covered by the slow plodding and groping industry of millions of men, each generation advancing slowly, but building on the work of its predecessors, gaining a knowledge of metals, learning how to vary and improve their properties, constructing better furnaces, forges and rolling mills, gradually advancing from the cold-riveted cylinder boiler of fifty years ago to the best types of Scotch marine, the locomotive, and water tube boilers of to-day, built with power rolls, flanging presses, and hydraulic riveters.

From the clickety-clack Cornish bull engine, painfully and slowly raising its ponderous piston to the top, and then dropping down with a crash and bang at perhaps thirty strokes a minute, to the noiseless Worthington pump of to-day, with a coin balanced on its cylinder head for hours while doing full duty; from Stephenson's "Rocket" with its twelve miles an hour over a rough track forty miles long, to the great ten-wheeler of to-day, carrying palace cars over smooth 100-pound rails across our continent in less than four days; from Watts's engine, requiring 62 pounds of water and 8 pounds of coal per HP. an hour to the triple-expansion engines of your modern cotton mills, consuming but 11 pounds of one, and $1\frac{1}{4}$ pounds of the other; from the tallow melted in a tin can on the cylinder head, to the union pressure oiler of to-day, which forces its 600° fire test oil with precision to the very spot wanted, and with just the requisite number of drops per minute; from the laminated boiler plate of fifty years ago, crude conglomerate of cinder and iron, mixed no one knew how, to the flange steel of to-day, with its exact constituents of carbon, of sulphur and phosphorus fixed by contract in advance; from the breast drill of our forefathers to our boring mill and turret lathe, — in one word, from the threshold of the nineteenth to the threshold of the twentieth century, the steam engine, and those who served it, have done a work for humanity worthy of greater epics than Homer's or Virgil's, of mightier brushes than Raphael's or Meissonier's; for the great song of steam is yet unsung.

It is, therefore, a bold word to prophesy that this true king of the nineteenth century is in danger of being dethroned, and his successor ready to take up his burden. Yet men like Rankine, Fleeming Jenkin, Redtenbacher, and Zeuner have been predicting this for some years, and our own Thurston has but recently fixed the exact limits to which further progress in the steam engine must of necessity be confined. He says: "With equally excellent design, construction, and management, we may expect the efficiency of the steam engine with increasing pressures to increase nearly as the logarithm for the boiler pressure."

According to this, if we can count in practice on 13 per cent. absolute efficiency with steam at 200 pounds, $15\frac{1}{2}$ per cent. would be the limit at 500 pounds, and 17 per cent. at 1,000 pounds steam pressure. And in this reasoning the increasing difficulties of steam production and boiler economy at a higher pressure have not been considered. This shows what has been done after a century of experimenting, and

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another century of most careful, well-directed, and even brilliant effort on the part of many men of genius.

The long line of analysis which brings out these conclusions may be said to have begun when, 101 years ago, a Yankee engineer, Benjamin Thompson (Count Rumford), imparted the discovery made by him in the cannon foundry at Munich, Bavaria, that "heat is not matter, but a form of energy." Other experimenters followed, but it was not until much later that Joule, in England, and Mayer, in Germany, determined and fixed the mechanical equivalent of heat. Early in this century, Sadi Carnot in France developed the theory of a perfect heat engine. Yet it was a long time before the clear reasoning of these men, although enthusiastically received and elaborated by scientific engineers in Europe and America, found its way into the designing room of engine builders. For a long time the steam engine was studied only in its mechanical aspects, and the striking success of Corliss, while a great stride toward mechanical perfection, tended rather to retard than to accelerate the study of the steam engine as a heat motor. Hirn's work at Mulhouse, Professor Lanza's work here in Boston, and Isherwood's practical experiments, finally roused mechanical engineers to the importance of considering the utilization and conservation of heat in the steam engine as the fundamental question of design. Even Ericsson, one of the pioneers of the steam engine, had previously turned to the hot-air engine to escape from those losses inseparable from the employment of steam. Naturally enough, then, many scientists and inventors turned again to the internal combustion engine, which had been previously experimentally developed by Barnet in England, Drake in America, LeNoir in France, improved by Brayton, Barsanti, and others, ably discussed and advocated by Dr. Siemens, and finally developed into a practical working machine by Otto in 1876.

Otto's master patent, though at first vehemently attacked, became the foundation on which Priestman, Crossley, Atkinson, Capitaine, Clerk, and others, built up a number of types with a gradual and satisfactory increase in economy. But they all worked in the beaten path of mixing a charge of gas and air, carefully compressing it, and igniting it for explosive action by various igniting devices. No one attempted a vital change in the cycle itself until Rudolph Diesel, in 1893, proclaimed his method and attempted the development of a practical working engine on the beautiful ideal of Carnot. After ex-

perimenting with various vapors more permanent than steam, and at first attempting both to add and withdraw the heat from the working fluid from without, he reached the conclusion that the atmosphere about us would furnish a cheap, endless supply of a permanent gas, available not only as the vehicle of heat, but as the means of evolving it from the fuel employed.

Rudolph Diesel is a Bavarian, forty years old. He received his early education in Paris, where his parents then resided, until they were forced to emigrate in 1870 by the decree of the moribund empire. He is a man of studious habits, a good mathematician and thoroughly versed in the science of thermo-dynamics, which he has made his life study. As a student at Munich he was a pupil of the celebrated Professor Linde, now well known as the inventor and builder of the excellent ice machine which bears his name. Since the publication of his lecture of June 16, 1897, he has been fairly overwhelmed with praise and congratulations by the leading professionals of Europe. Perhaps no better gauge of the strong common sense and real greatness of the man can be found than the fact that all this praise and adulation have not turned his head in the least. He remains the same simple, earnest, conscientious student that he was before his great invention dazzled the experts in his line of engineering.

I was particularly struck with the simplicity, and I might almost say humility, with which he spoke of his great achievements. He considers his present success only as an incentive and a stepping-stone to further work and progress. He is very accurate in all his statements, and thoroughly honest. Nothing can induce him to confound even his most sanguine hopes with a promise of any future success. He patiently and good humoredly answered all my questions, and was instantly ready to show me authorities for his statements from the carefully chosen books of his extensive library.

As an engineer he is more theoretical than practical, but has now at his command some of the best practical talent of Germany. Professionally well equipped and clear in his ideas, he is so simple and amiable in his manner that it is a pleasure to work with him, and these characteristics of the man promise to make the working together of the various interests in the many countries in which he has issued licenses satisfactory and beneficial to all, and will make a rapid progress in the practical development of the invention possible.

Mr. Diesel has been at work on the theories on which this motor

is constructed ever since he was a student at the Munich Polytechnic School. For the past fifteen years he has devoted himself almost entirely to this work. He even built a small experimental motor in Paris many years ago, the working of which enabled him to modify his first theories considerably. He, however, took the precaution to have the parts of this motor made in different shops to prevent his ideas and processes from becoming known. In 1892 he made his applications for his first patents in different countries.

When his book was published it hardly went farther than into the libraries and studies of men specially interested in the theory of thermo-dynamics. But Mr. Buz, of Augsburg, the general manager of the great machine works there, placed means and men at the disposal of Mr. Diesel, to enable him to work out his theory in practice, and a 12 horse-power motor was built there, on which many experiments were made. The improvements suggested were embodied in a second machine of the same size, and from this was evolved the 20 horse-power motor which established the working type now adopted. Mr. Fr. Krupp, of Essen, the German steel king, also became interested in the matter. Mr. Diesel moved to Munich so as to be able to give his whole time to this work.

In the meantime, in 1895, a Mr. Schmidt, of Cassel, worked out and exhibited a steam engine working with highly super-heated steam. For the time this motor attracted the attention of the engineering world. Its defects were, however, so apparent that it did not come into general use, but it did serve to withdraw attention from Diesel and his work. On the 16th of June, 1897, Mr. Diesel delivered a lecture before the National Society of German Engineers at Cassel, in which he not only developed his theories, but exhibited in drawings the actual construction of his motor, and gave some data in regard to practical results obtained at Augsburg. Professor M. Schroeter followed Diesel in further development of the theory of the motor, and gave in detail the results of tests made by him on the first experimental motor, and stated his conviction that the motor was now ready for commercial work. (These essays were published in the "Zeitschrift des Vereins Deutscher Ingenieure" of July 10, 17, and 24, 1897.)

At the conclusion of these papers a wave of enthusiasm swept over the large audience of professional engineers, and the desire naturally arose to see the motor at work. Mr. Diesel extended invitations

FIG. 1. — RUDOLPH DIESEL.

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to all engineers and manufacturers to visit the works at Augsburg and to examine and test the motor for themselves. This invitation had been so generally accepted, that for the next nine months the motor was practically on exhibit for every hour of the day, under the closest inspection by engineers, not only from Germany, but from every civilized country. It was therefore necessary to keep it running as a petroleum motor, and not until April, 1898, was it possible to dismantle the engine in order to make the slight but important changes to adapt it to experimental work on gas.

Mr. Diesel's idea was to follow Carnot's cycle strictly, obtaining the lower isothermal and adiabatic curves by compression, and the upper ones by combustion and expansion. For a long time he experimented with various vapors, which, under normal conditions, are far above their points of condensation.

Ammonia vapors, especially, seem to have the properties best suited to the theoretical process. But great difficulties in handling them were encountered in practice. In the endeavor to replace them he was naturally led to experiment with air. Up to this time he had necessarily applied his heat from without, and was subjected to the losses and limitations due to the metal walls through which it had to pass. He was then subject to the same losses which had defeated Ericsson, and was compelled to make the step which made his motor an internal combustion engine. Starting out, then, with the intention of improving the caloric process of the steam engine, he reached, in a round-about way, means similar to those employed in gas and oil engines. But this similarity is strictly limited to the *fact* of internal combustion, the *method* of combustion being radically different. Further, finding that to begin his compression isothermally led him into pressures which must, in our present practice, be considered excessive, he abandoned that part of the Carnot cycle and made his compression adiabatic throughout, thus reducing the necessary pressures from over 100 atmospheres to between 30 and 40. When, as in the history of the steam engine, these higher pressures become practically feasible, a return to the original complete process may become advisable. Mr. Diesel's fundamental invention is then really a process for converting heat into work; this, of course, has been supplemented by other inventions naturally growing out of the persistent and logical development of a practical machine to operate on this process.

It was Diesel's first intention to build a motor with three cylinders,

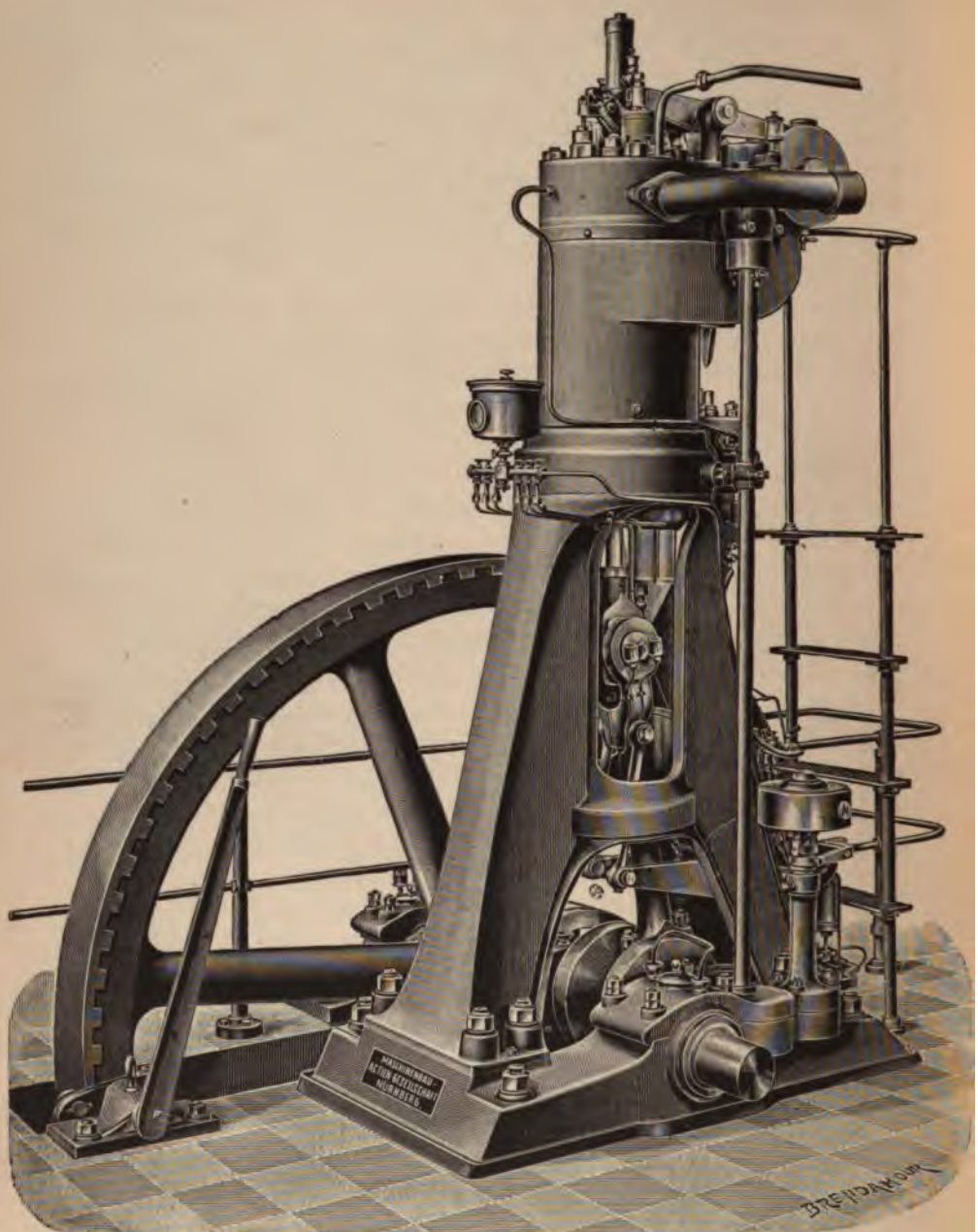

FIG. 2.—20 H. P. DIESEL MOTOR, GERMAN TYPE.

embodying compound compression and compound expansion, and one of this type has been built at Augsburg, and is to be thoroughly tested on producer gas. But the development of the single cylinder type has been so satisfactory, and the demand for them has become so great, that at present the German shops are busy to their fullest extent, building this simpler form. As this form has reached an absolute efficiency of 30 per cent., and is in every way a simple and practical machine, there is at present no reason for developing the compound motor. The cut here given (Figure 2) represents the first of these 20 HP motors, built by the Nuremberg Machine Works. This motor was exhibited at the Electrical Exposition in New York City, held in May, 1898. In appearance it resembles a vertical marine engine. A strong base plate supports the main journals of the crank shaft, outboard bearings being provided for the shaft extensions which carry the fly-wheel and pulley. Bolted to the base plate is a stout *A*-frame containing the guides. In the rear leg of this frame a small air pump is supported. On the top of the frame is placed a cylinder open at bottom. Its top is closed by a head cast in one piece, in which are contained one suction valve for air, one discharge valve for spent gases, and a needle valve for the fuel. The admission to the casing of this fuel valve is controlled by a stop valve which can be instantly closed to shut off the supply of fuel. Besides this, there is a starting valve used only in starting the engine. Cylinder and air pump are water-jacketed. This water jacket was not used in the earlier experimental engines, but is found advantageous in keeping the temperature of the working parts uniform. As the temperature of combustion is so much lower than that of the explosion type of engines, a much smaller amount of water suffices for this. In the earlier German engines the main shaft and crank are bored for water cooling. This, however, grew out of the practice of Krupp's Steel Works of boring all small shafts produced. The practice has been discarded in England and in America as unnecessary. The air pump is driven by a set of levers attached to the main cross-head. Conveniently placed to one side is an air vessel known as the starting tank, connected by copper pipe to the air pump, and to the fuel valve casing.

The operation is as follows: On one down stroke the main cylinder is completely filled with pure air; the next up stroke compresses this to about 35 atmospheres, creating a temperature more than sufficient to ignite the fuel. At the beginning of the next down stroke

the fuel valve opens, and the petroleum, atomized by passing through a spool of fine wire netting, is injected during a predetermined part of the stroke into this red-hot air, resulting in combustion controlled as to pressure and temperature. This injection is made possible by the air in the starting tank, which is kept by the small air pump at a pressure some 5 to 10 atmospheres greater than that in the main cylinder. A small quantity of this air enters with the fuel charge, which it atomizes as described. When the motor is running at full load a very small quantity of injected air suffices, and the pressure in the air tank steadily rises. At half load, with less fuel injected, more air passes in. For this reason, the starting tank is made large enough to equalize these differences, and a small safety valve is provided on the air pump.

The petroleum is pumped into the fuel valve casing by a small oil pump bolted to the base plate. This pump is arranged to pump a fixed maximum quantity of petroleum. A by-pass is provided so that this whole quantity, or any portion of it, can be returned to the supply tank. The governor controls the action of this by-pass valve, closing it just long enough to compel the exact quantity of the fuel required to pass into the fuel valve casing. As this requires only the movement of a small light wedge, the regulation is accomplished with great exactness. In this regulation resides a great advantage for the Diesel motor. The full charge of air being always supplied for complete combustion, it matters not whether the governor permits one or fifty drops of petroleum to enter the working cylinder at each motor stroke; the combustion is always complete. Thus variations in excess of air over that theoretically necessary, from 26 to 116 per cent., have been measured, and the analysis of the spent gases shows no trace of unburnt carbon or hydrogen. It is hard to conceive a more perfect combustion than that which takes place when fuel is sprayed, finely powdered or atomized into red-hot air, just beginning to expand. To stop the motor it is only necessary to close the valve which admits the petroleum into the fuel valve casing. The valve gear consists of a series of cams placed on a shaft journaled on brackets cast on the cylinder.

In starting the motor a hand lever is pulled to one side, throwing all these cams, except the exhaust valve cam, out of gear, and throwing a special cam into gear with the starting valve. A few strokes of the petroleum pump by a hand lever inject a small quantity of petro-

leum into the fuel valve casing. The fly-wheel is thrown over by a lever a trifle beyond the upper dead point. The fuel throttle valve is opened, and by a turn of the hand wheel communication is established between the air tank and the starting valve. A single charge of highly compressed cold air enters the cylinder, sufficient to give two revolutions of the fly-wheel at moderate speed. At the close of the first revolution the starting valve cam is automatically thrown out of, and

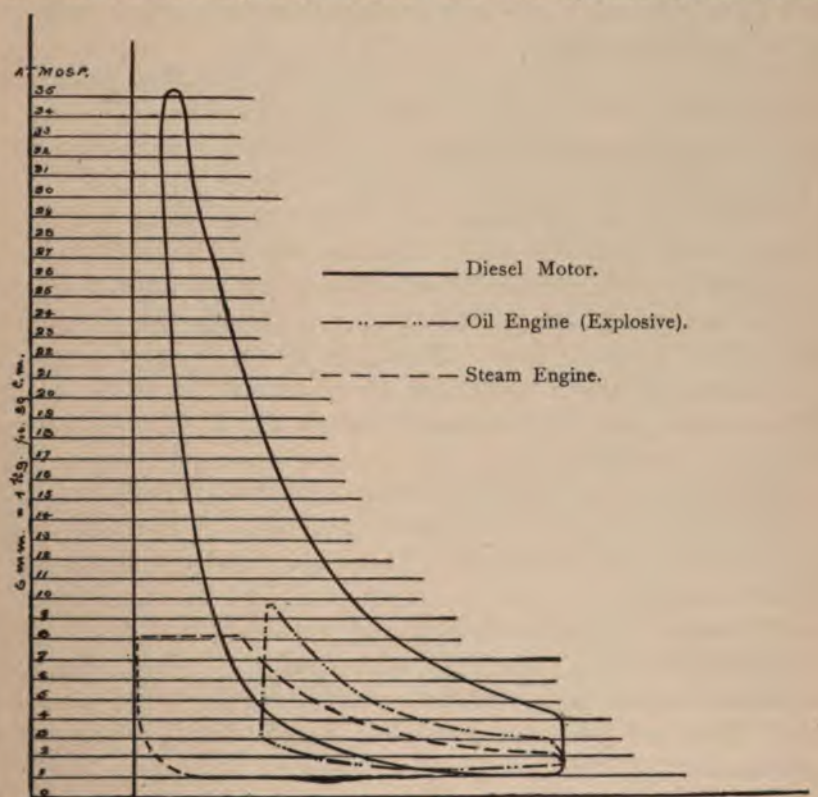

FIG. 3.—COMPARATIVE DIAGRAMS. DIESEL MOTOR, OIL ENGINE, AND STEAM ENGINE.

the other cams into, gear, and thus on the second revolution a full charge of air is drawn in and compressed, and in less than thirty seconds the motor is running at full speed.

Mr. Diesel makes a sharp distinction between the temperature of ignition and the temperature of combustion; the first is a constant value at each pressure, and dependent only on the physical qualities of the fuel, the higher the pressure the lower the temperature of igni-

tion. The temperature of combustion on the other hand is variable, depends on many conditions, and especially on the quality of the air by which the combustion is maintained, but it is always higher than the temperature of ignition.

Diesel's radical departure from all previous practice is in generating a combustion temperature by mechanical compression of pure air, utilizing this temperature to ignite the fuel, and by so introducing the fuel that the heat lost by expansion is practically balanced by the heat added by combustion.

Before the completion of this perfect engine, certain critics of Diesel's theories contended that the dimensions of the cylinder and all other working parts would become so great as to make it impracticable to build such engines. But in Diesel's engines the increase and the decrease in pressures are so gradual that there is no shock. The change from one to the other is always accomplished at a dead point. In all motors relying on explosion for their moving force, and even in the steam engine, there is a direct blow at the moment of ignition or admission. I present here a drawing on which indicator diagrams of a high-pressure steam engine, of an explosion-type motor, and of a Diesel motor have been drawn, based on the same piston displacement. (Figure 3.)

Diesel's and the explosion motor diagrams can be directly compared, since both work on the four-stroke cycle. The steam engine diagram should be quadrupled. This disposes of the objections just referred to.

These second and third diagrams (Figures 4 and 5) are graphic comparisons of the Diesel motor, with a number of the best petroleum motors as to economy in fuel and volume swept by the piston per second. They are given on the authority of Professor Hartmann, well known as a careful and conscientious observer in this field.

The abscissæ represent piston displacement in liters per second, the ordinates petroleum consumption in grams per hour, both figured on the effective or B. H. P. The full lines (Figure 4) embrace the results for full loads, the dotted lines (Figure 5) those for half load. The comparison is between engines which burn ordinary safe lamp petroleum or kerosene; results obtained on benzine or naphtha are not considered, since motors depending on such dangerous fuels can never be generally adopted for industrial purposes. The calorific value of these highly inflammable and explosive liquids is no greater than that of safe kerosene or of fuel oil.

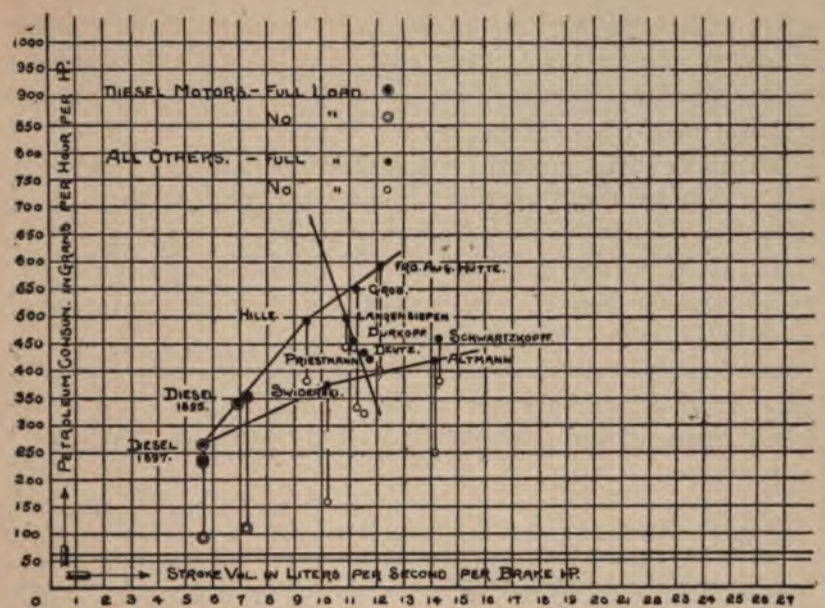

FIG. 4. — COMPARATIVE CHART. FUEL CONSUMPTION AND STROKE VOLUME. FULL LOAD.

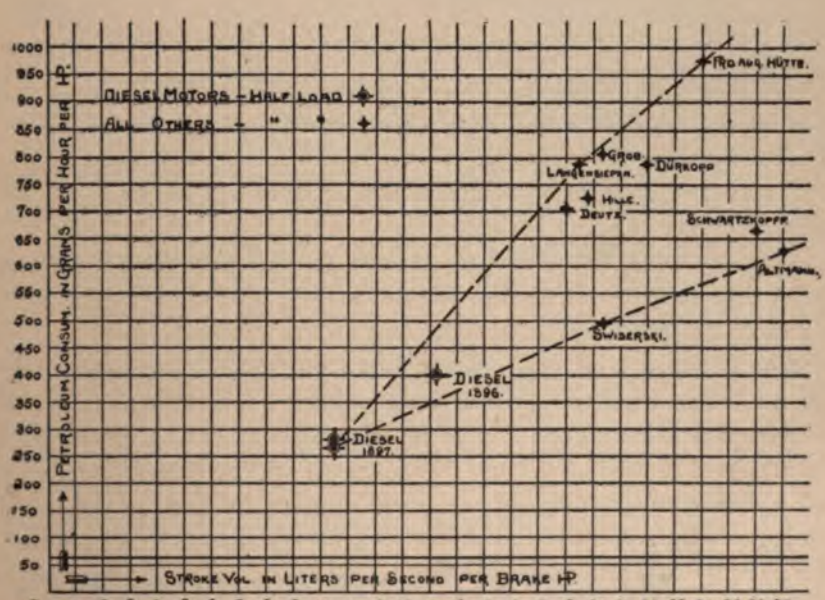

FIG. 5. — COMPARATIVE CHART. FUEL CONSUMPTION AND STROKE VOLUME. HALF LOAD.

You will notice that we find the Diesel results in both cases near the apex of the angle; or, plainly put, both at rated capacity and at half load the Diesel motor shows the smallest cylinder dimensions and the least expenditure of fuel.

Remember that the others represent the best results from engines carefully developed and improved in all mechanical details, while the Diesel motor is but the third one ever built, and that in its construction the practical realization of the theoretical cycle was the primal consideration, mechanical improvement being left for the future commercial exploitation of the machine.

Broadly speaking, the absolute efficiencies of the best known heat engines of to-day range about as follows, taking into account actual calorific values of the fuel and effective or brake horse power:

	Per cent.
Small auxiliary steam engines, pumps, etc.	$\frac{6}{10}$ to 1
Plain slide valve engines in good condition	3 to 5
Single cylinder Corliss engines	6
Compound condensing engines	8
Reheating compound or triple expansion steam engines	12
Best oil engines (explosion type)	16
Best gas engines (explosion type)	19
Diesel motor	28 to 30

All these are compared when running steadily at full load or rating, at point of best economy. But in a large majority of the applications of all these prime movers, the exigencies of the service require them to be run frequently at three-quarters and half load for a large part of their daily service.

It is conceded that in most engines the internal frictions or mechanical losses are a fixed amount, so that a loss of 15 per cent. at full load becomes 30 per cent. at half load. And thermal losses increase even more rapidly, for instance, in steam engines by cylinder condensation. In gas and oil engines the absolute efficiencies have in some cases shown a measured loss of nearly 60 per cent. In the Diesel motor the thermal efficiency is shown to increase with decreasing loads, thus counteracting in a marked degree the loss in mechanical efficiency which it shares with the other machines. From a number of carefully checked tests I found the average drop in absolute efficiency from full to half load to be only 15 to 16 per cent. in the Diesel motor.

So promptly and easily does it respond to a change of load that a sudden addition of 80 per cent. to the electrical load on the Diesel motor at the Electrical Exposition at New York, by the throw of a switch, was not noticed by observers of the engine or the lights, though promptly registered by the ammeter. For variable load, then, the Diesel motor will show in practice a much greater superiority over all rivals than that apparent from the tabular figures just given.

Up to the beginning of 1898 the Diesel engine had been successfully run only on refined petroleum or kerosene, and this was the fuel used at the Electrical Exposition. During July and August this same engine was subjected to a series of tests, extending over ten weeks, under the supervision of Professor James E. Denton, of Stevens Institute. He reported as follows:

"Tests were made with ordinary domestic kerosene, and with the various grades of petroleum used as fuel under steam boilers, which covered the operation of the engine for upwards of 250 hours, to observe the behavior of the oil and the condition of the interior of the engine after using each oil. During this time economy tests were made of from 1 to 10 hours' duration, the principal commercial results being:

"1. With ordinary colorless domestic kerosene of 120 degrees Fahr. flash, 150 degrees Fahr. fire test, and 0.784 gravity, at about 187 revolutions per minute, an average of 20.8 brake horse power was developed, with an oil consumption of 0.534 pounds, or 0.082 United States gallon, per hour per brake horse power; 13.05 brake horse power with an oil consumption of 0.586 pounds, or 0.0896 United States gallon per hour per brake horse power; and 8.78 brake horse power with an oil consumption of 0.72 pounds, or 0.110 United States gallon per hour per brake horse power. This shows an efficiency on brake horse power of 25.8, 23.5, and 19.0 per cent. respectively. The corresponding indicated horse power efficiencies were 37.7, 41.8, and 41.2 per cent. respectively. These results practically confirm the tests made on an engine rated at 19 brake horse power, at Augsburg, Germany, by Professor Schroeter and other experimenters, which for 17.33 English horse power showed an oil consumption of 0.54 pounds, or 0.0819 United States gallon of American kerosene per hour per brake horse power; and for 9.315 English horse power an oil consumption of 0.63 pounds, or 0.0956 United States gallon per hour per brake horse power, the efficiencies being as follows:

	17.33 HP.	9.315 HP.
Thermal efficiency on indicated HP.	34.15%	38.18%
Thermal efficiency on brake HP.	25.81%	22.12%

"The same increase in indicated efficiency, with reduction of load to one-half shown by the German tests, is found in the New York tests. The mechanical efficiency or the per cent. of the indicated power utilized at the brake of the New York motor was not as great as that of the motor tested in Germany — a result which is possibly attributable to the insufficiency of the foundation of the New York motor, which, by permitting excessive vibration, may have caused a waste of power between the cylinder and the brake. The New York motor showed the greater indicated efficiency, however, which is probably due partly to the slight difference of maximum pressure, and partly to the higher temperature of cooling water, reducing the jacket waste. The heat balance for the two cases is as follows:

HEAT BALANCE.

	New York.		Augsburg.	
	21.51	8.78	17.33	9.315
Heat of combustion accounted for by indicated power	37.2%	41 2%	34.7%	38.9%
Removed by jacket	35.4%	37.4%	40.3%	45.1%
Remainder	27.4%	21.4%	25.0%	16.0%
Total heat of combustion	100.0%	100.0%	100.0%	100.0%

"Examination of the interior of the engine during the use of the kerosene showed that there was no deposit on the surfaces other than an infinitesimally thin film of lampblack on the cylinder and piston head, which did not increase with time. The bore of the cylinder was clean and polished.

"2. With Pratt's fuel oil, which is a dark straw-colored, clear petroleum, of 200 degrees Fahr. flash, 268 degrees Fahr. fire test, and 0.852 gravity, considerably used as a steam boiler fuel, at practically the same revolutions, 20.07 brake horse power were developed, with an oil consumption of 0.613 pounds, or 0.0862 United States gallon, per hour per brake horse power; and 12.56 brake horse power with an oil consumption of 0.681 pounds, or 0.0958 United States gallon, per hour per brake horse power. The operation with this oil was attended with the same insignificant lampblack deposit.

"3. With a black, clear, Pennsylvania petroleum, known as 'Eagle' fuel oil, of 249 degrees Fahr. flash, 296 degrees Fahr. fire test, and 0.849 gravity, at practically the same speed, 20.75 brake horse power

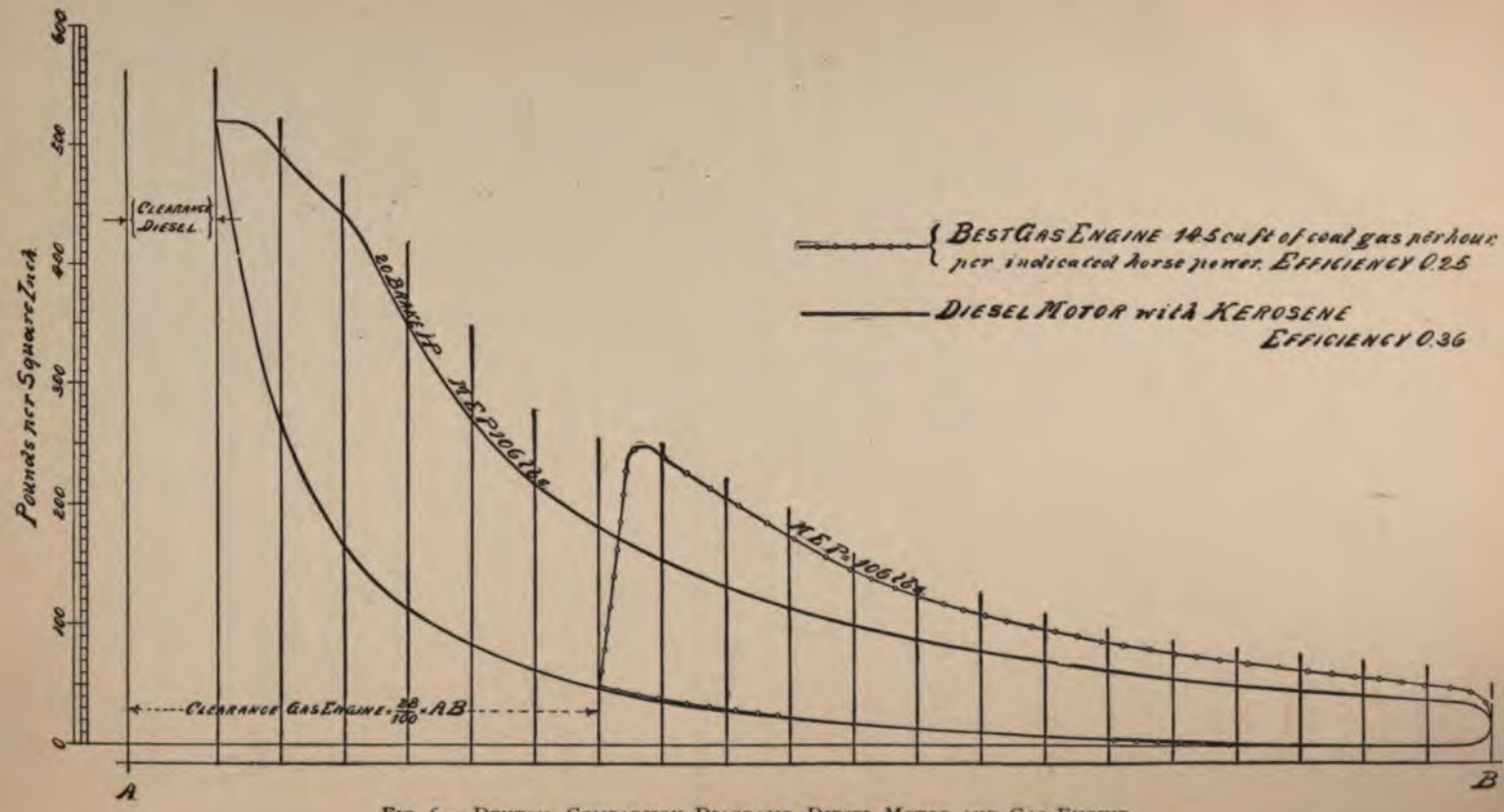

FIG. 6.—DENTON, COMPARISON DIAGRAMS, DIESEL MOTOR AND GAS ENGINE.

were developed, with an oil consumption of 0.56 pound, or 0.0784 United States gallon, per hour per brake horse power. This oil left absolutely no deposit in the cylinder.

"4. With Lima fuel oil, a black, clear petroleum of 0.856 gravity, at about the same speed, 20.73 brake horse power were developed, with an oil consumption of 0.59 pound, or 0.0826 United States gallon, per hour per brake horse power; and 10.77 brake horse power, with an oil consumption of 0.672 pound, or 0.0941 United States gallon, per hour per brake horse power. The operation with this oil was attended with no deposit in the cylinder whatever.

"5. With California crude oil, a black, clear petroleum of 0.846 gravity, with practically the same revolution, 20.07 brake horse power were developed, with an oil consumption of 0.626 pound, or 0.0887 United States gallon, per hour per brake horse power; and 11.44 brake horse power, with an oil consumption of 0.699 pound, or 0.099 United States gallon, per hour per brake horse power. This oil left absolutely no deposit in the cylinder.

"With all these oils the engine started instantaneously and operated very steadily. The action of the valve gear is very smooth and practically noiseless. The combustion occurred with perfect regularity, and was accompanied with no noise other than that due to the pulsation of the floor under the engine. There was also no noise from the exhaust of the engine audible a few feet distant from the chimney into which the exhaust pipe led.

"The exhaust gases with all of the oils carried no soot, a piece of white paper being unsoiled by the impingement of the gases against its surface.

"No deposit was found in a drum forming part of the exhaust pipe, after the entire 250 hours of operation of the motor."

Professor Denton further illustrates the results of his tests by comparing average indicator cards from a gas engine and the Diesel motor. (Figure 6.)

This same engine was afterwards exhibited at the Mechanics Institute Fair, from October 10 to December 3, and during this entire time was run on a low grade of fuel oil, costing about three cents per gallon, f. o. b. tank car, Boston. During this nine weeks' run no fouling whatever was experienced, so that it was possible to run a test the day after the fair closed, without any previous grooming of the engine or any examination of its working parts or valves. This test shows

even more favorable results than those obtained by Professor Denton. The engine has since been moved to Worcester, Massachusetts, where it is in daily operation.

These remarkably favorable results obtained with low-grade fuel oils have, for the present, almost nullified the commercial importance of developing the Diesel engine as a gas motor. But experiments are going on in Germany, both with illuminating gas, power gas, and even blast furnace gases. These will be continued through the year, and the results will be communicated to the American Company.

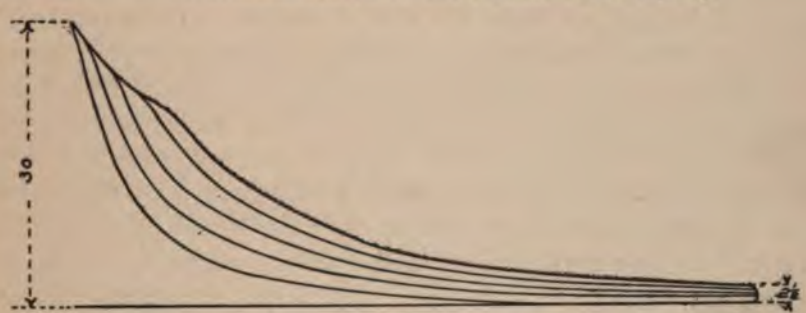

FIG. 7.—INDICATOR DIAGRAMS, DIESEL MOTOR.
Variable Load, Augsburg City Gas.

I take pleasure in presenting an enlarged view of an indicator diagram (Figure 7) taken from the motor while running on Augsburg City gas, merely to show you that the same beautiful and economical cycle is possible with gas as with petroleum.

In the January number of the *Sibley Journal* is found an instructive article by Prof. R. H. Thurston, of Cornell University, concerning the thermal efficiency of steam engines. Professor Thurston refers to the diagram by Capt. H. R. Sankey, Secretary of the British Institution of Civil Engineers, in which he compares the exceptionally economical Leavitt engine of the Louisville (Kentucky) Waterworks, with the performance which would be possible could the Rankine ideal be reached. Rankine first proposed this ideal cycle on January 17, 1854, and Clausius describes the same cycle in 1856, quite independently of Rankine. In short, the Rankine cycle takes in all the usual activities of the steam engine, but takes account only of those losses which are in their very nature inseparable from the cycle. All those vexatious and costly losses which even the best practice does not now, nor ever can, eliminate from the problem, and which may be classed

under the general heads of "radiation" and "friction," are in this ideal cycle considered as non-existent. In Professor Thurston's paper the comparison is made on an equal output in effective work. This I have changed for the purpose of better comparison in this case, by beginning with an equal expenditure in heat units at the beginning of the cycle, thus showing the difference in the output, in place of in the original total expenditure of heat. For the careful elaboration of these diagrams, credit is due to Mr. A. J. Frith, M. E.

In the case of the Diesel engine I start also with the same total expenditure in heat, and trace the flow of this "broad river of heat" through the entire cycle, showing the losses as actually found from a number of tests made on a 20 horse power Diesel motor at New York. While there is every reason to believe that in a larger Diesel engine the losses both from radiation and from friction will show a smaller percentage of the total heat expended, still it would be unfair and unwise to bring into the illustration any merely theoretical deductions. It is better to show the facts as they are, and I content myself simply with pointing out that we are really comparing a 600 horse power steam engine with a 20 horse power Diesel motor. Every fair-minded engineer will concede that for a larger unit the advantage would be greater for the Diesel engine. It is but proper to remark that at the present writing no Diesel engine larger than 150 horse power has yet been built, although units of 300 and 400 horse power are now in process of designing. No special difficulties are apprehended, and the advice of such eminent authorities as Lord Kelvin and Professor Hartmann is in every way favorable to the larger units.

Diagram (Figure 8) shows the reproduction of Captain Sankey's original graphic representation of the actual results obtained during the test of the Leavitt pumping engine at Louisville.

As Professor Thurston says, "This is a very exceptionally good illustration of thermo-dynamic action, and the wastes are very much smaller than are commonly observed in the operation of even good classes of steam engines."

The entire river of heat with a discharge of 183.600 heat units per minute flows from the fire grate. To the right is seen the loss by radiation in the boiler itself. But about three-fourths of the entire flow turns toward the steam pipe. Considerably over one-fifth, however, flows toward the left, toward the economizer, where it loses again by radiation, but is reënforced by a brook coming from the hot well

through the feed pump, and is further joined by a rivulet of returned heat from the jacket water, altogether forming a tributary of no mean size, joining the stream flowing into the steam pipe. Here again, at the bottom, the small rivulet escapes through radiation, but the main body passes on into the engine, where we have the smaller losses by the stream which runs into the jackets, the other which represents the mechanical friction in the engine, and the third, the radiation. By far

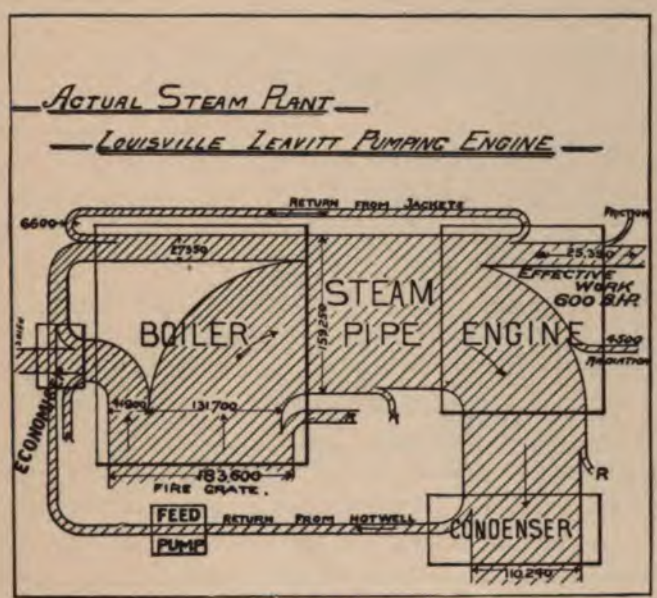

FIG. 8.

the larger stream, however, is lost in the exhaust steam. In passing through the condenser, however, a small brook is diverted toward the feed pump to again do useful work, as above described. We have then (in the upper right-hand corner of the diagram) left but the small fraction of 25,390 heat units, or say in effective work 600 brake horse power, which represents only 13.83 per cent. of the total which is given to the engine; or, as it is customarily expressed, this most excellent engine plant, representing the highest development of modern steam engine practice, has realized an absolute efficiency of only 13.83 per cent.

Diagram (Figure 9) shows the same plant running on Rankine's ideal cycle. In this friction and radiation are swept away by one

happy stroke of the imagination. While a larger stream of heat is diverted to the economizer, this has become so effective that it only allows a very small current to escape toward the chimney. In fact, this represents less than 8 per cent. of the original volume of flow. From the economizer a much larger stream, augmented by the brook flowing from the hot well, re-enters the boiler, so that a total of 178.400 heat units enters the steam pipe, more than a quarter of which does

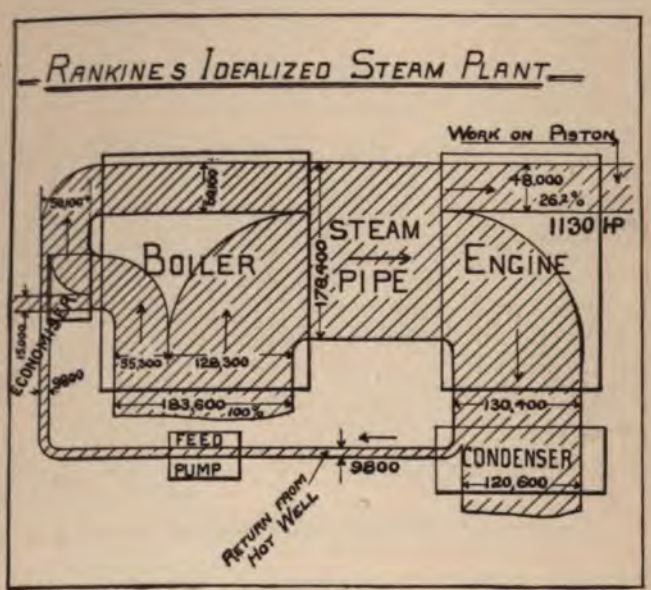

FIG. 9.

useful work on the pistons. But the other three-fourths finds its way as before to the condenser.

In the stream which finally turns our wheels we find 48,000 heat units, giving us 1,130 horse power, or the absolute efficiency of the Rankinized engine is 26.2 per cent. This, then, we may consider as the ideal possibility in steam engine practice, toward which we may strive, but which can never be reached, because we cannot dispose of radiation and friction in actual practice as easily as we have done on paper.

Diagram (Figure 10) shows Captain Sankey's method applied to the Diesel motor, with the same broad river of heat, having a constant flow of 183,600 B. T. U. per minute. The bulk of this enters the

cylinder on its working stroke, but we have before lost more than 30 per cent. from three causes: The one is the actual negative work done in compressing the fresh air of the charge in the main cylinder, and which represents 30,700 B. T. U. A very small stream is the heat expended in compressing air in the air pump, and a third stream, aggregating 22,500 B. T. U., represents the loss by cooling, which flows into the jacket water during the period of compression. The two

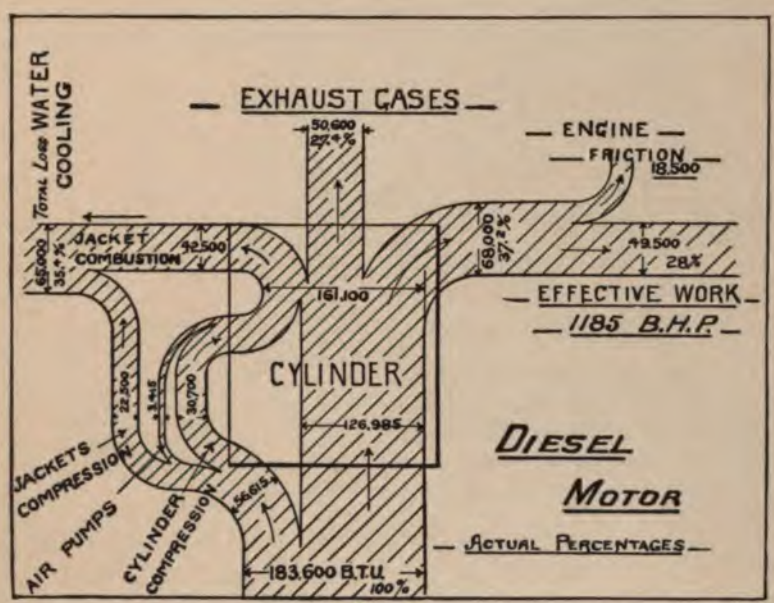

FIG. 10.

losses first mentioned flow back again into the cylinder during the period of combustion in the working stroke, so that we find their total at 161,100 B. T. U. But during combustion we lose again, as shown in the upper left-hand corner, a large stream of heat which flows into the cooling water of the jackets during this period, so that the final and total loss of heat which has flowed into this cooling water amounts to 35.4 per cent. of the total flow. Directly upward is shown a stream of heat amounting to 27.4 per cent. of the original flow, which we lose in the exhaust gases. To the right a good-sized stream representing 37.2 per cent. flows into indicated work. From this, however, we lose a large amount, viz.: 18,500 B. T. U. in engine frictions. Comparing this with the loss shown in the first diagram of the Louisville engine,

the stream looks very large. In explanation, however, we must remember that the steam engine has four effective or motor strokes to one in the Diesel engine. As the latter has to do its whole work in this one stroke, while the frictions retard it in the whole four strokes, it would be entitled to a percentage loss four times as great as that of the steam engine, without being subject to criticism as a mechanically inferior device. Furthermore, the total stream of heat on which this

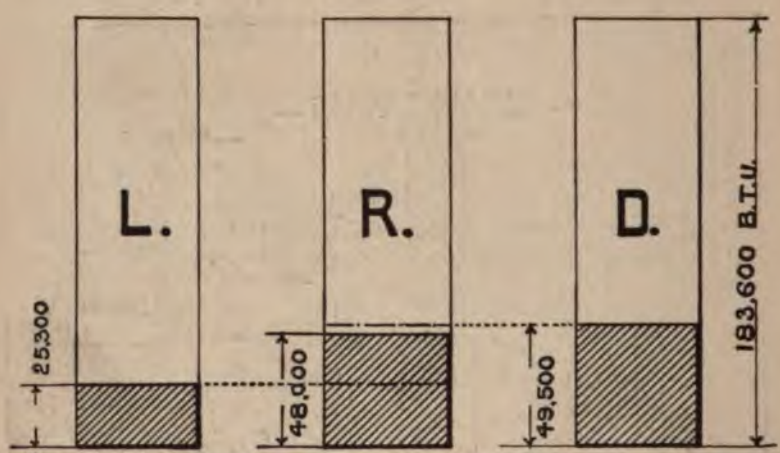

FIG. 11.—COMPARATIVE EFFICIENCIES. LEAVITT, RANKINE, DIESEL.

percentage is to be figured is more than double as large as that which flows into the steam engine. If, then, this outflow in friction should appear eight times as large in actual quantity as that from the steam engine, it could not be considered abnormal.

Finally, we find a broad stream with a flow of 49,500 B. T. U. in the effective work of the engine, a total of 1,185 horse power, or the Diesel motor has shown 28 per cent. absolute efficiency. I must here remark that this 28 per cent. represents a fair average from a large number of tests, while I might have chosen an extreme case which shows over 30 per cent. But I prefer to illustrate in this manner results which we have very frequently obtained, and feel confident of being able to reproduce and even to excel, in all our engines.

Diagram (Figure 11) shows a comparison of the three engines by a representation of areas simply. In each case the large rectangle represents the total of 183,600 B. T. U. with which each engine is charged. The smaller shaded portions of the three rectangles show in

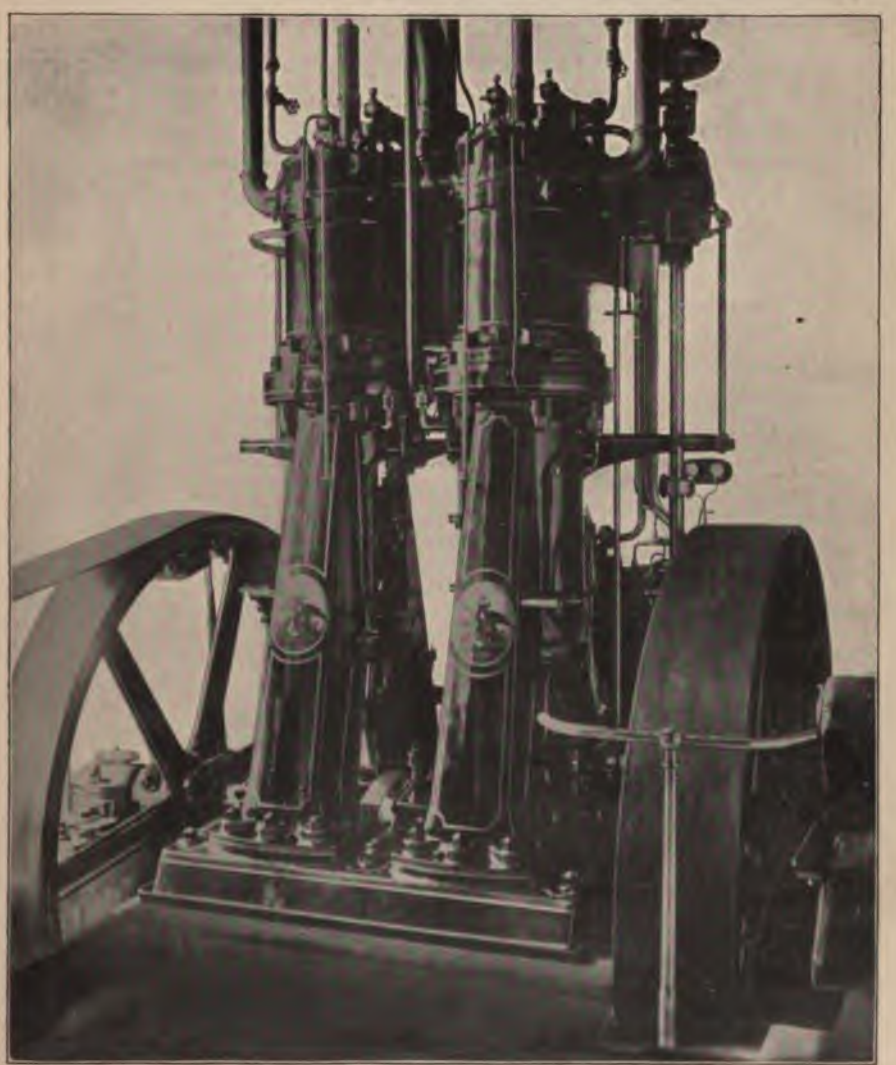

FIG. 12. 60 H. P. TWIN DIESEL ENGINE, GERMAN TYPE.

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each case the return made. The rectangles are marked "L" for the Leavitt engine, "R" for the Rankine cycle, and "D" for the actual cycle of the Diesel motor. This shows at a glance that the Diesel motor has in actual practice far outstripped the theoretical possibilities of the steam engine.

Turning again to the diagram (Figure 10), let us examine where further savings can be effected in the Diesel motor. The engine frictions will be no doubt reduced in larger engines, and here is offered a good opportunity for the ingenuity of the designer and the skill of the manufacturer, but after all the field is a rather limited one. The next loss, that through the exhaust gases, can in many cases be very largely reduced by utilizing this heat for heating water or even producing steam for the heating of work rooms, or for various mechanical purposes. The largest loss, that shown toward the left, as the total loss to the cooling water, can also in many cases be utilized for the same purposes, and it is simply a question of temperatures and quantities whether these two streams are to be separately utilized or first combined.

These, however, are questions which can only be discussed here in a general manner, the solution in each case depending on the various local conditions of the problem. If, however, we may assume that in most cases we can utilize one-half of this waste, we would thereby nearly double the absolute cfficiency of the entire plant. In a measure these collateral economies have the same right to be considered as those obtained from the economizer, condenser, and steam jackets in the steam engine; and in this connection the Diesel engine has the comparative advantage that these streams of loss flow at higher temperatures, and can, therefore, in practice be more readily utilized.

Two Diesel engines have thus far been built in America. One is a two-cylinder engine of 60 actual HP., which is driving an Edison generator for 600 lights in the electric plant of the Anheuser-Busch Brewery, in St. Louis, and which they report is giving them an actual HP. at a cost of about one-fifth of a cent per hour in fuel oil.

Careful tests made on the same show the greatest fluctuation in voltage to be $\pm \frac{1}{8}$ volt at full load and $\pm \frac{1}{16}$ volt at half load. This engine has been built entirely according to the German designs (Figure 12). A second engine which presents a wide departure from this is a $2\frac{1}{2}$ HP. marine engine built from our own designs at Newark, New Jersey. This is still in its experimental stage, but it has been run at

speeds varying from 150 to 400 revolutions, and its very simple reversing gear is entirely successful. If the experimental work cut out for it can be completed in time, it will be put on a boat during the summer. (Figure 13.)

A number of stationary engines of 30 HP. are now being constructed. They are entirely self-contained, trunk engines, with two fly-wheels each, and are about 4 feet less in height than the German type. In Europe twenty firms have been licensed to build Diesel motors during the past year, and between 70 and 100 motors are now in actual service.

The engine is, of course, in its infancy, and like all new machines will go through its period of complexity, and finally develop into a very simple and practical form, ready and capable of performing all or nearly all the functions of a steam engine at considerably less cost; and it is my firm belief that before the end of the century the name of Rudolph Diesel will be written on the same scroll with that of James Watt.

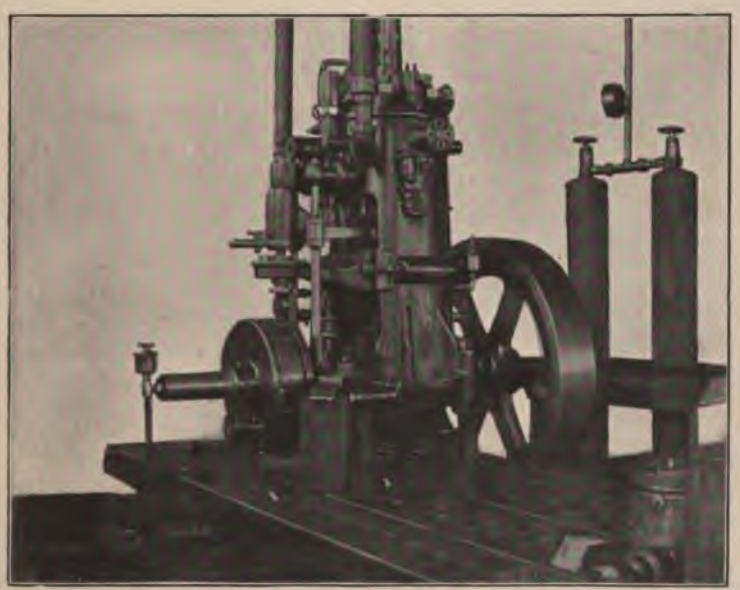

FIG. 13. 2½ H. P. REVERSIBLE DIESEL ENGINE, AMERICAN TYPE.

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AN AMERICAN RAILWAY IN COLOMBIA.

By FRANCIS R. HART.

Read March 23, 1899.

ALTHOUGH the Republic of Colombia is the nearest South American neighbor to the United States, the fact that it requires an introduction, both geographical and descriptive, to the majority of North Americans, will make an account of the American interests in that country clearer if prefaced by a brief sketch of its history and physical characteristics. It was Columbus himself who in September, 1502, discovered Cape Gracias á Dios, and in October of the same year touched at what is now Bocas del Toro on the Colombian coast.

Colombia occupies that corner of South America which is connected with Central and North America by the Isthmus of Panamá, the isthmus being politically a part of Colombia. Its coast line on the Caribbean Sea is a little under one thousand miles, and on the Pacific it extends south to its boundary with Ecuador, the southern neighbor of Colombia. On the east and southeast it is bounded by Venezuela and Brazil. In extent it reaches from the equator to about twelve degrees north latitude. In area it is more than double that of the Spanish peninsula, or about 500,000 square miles. The settlement of the country by the Spaniards began in the second decade of the sixteenth century, and by the middle of that century their power was fairly established.

Cartagena, with which this paper will more particularly deal, was founded about 1533 on the beautiful land-locked bay of the same name. In those days of conquest, when the Caribbean Sea was the great hunting ground for freebooters and buccaneers, a safe storehouse for treasure, and a rendezvous for the ships of Spain were a necessity, and led to the construction of strong fortifications to guard the town and harbor of Cartagena, fortifications which stand to-day for the most part as solid and perfect as when first built three centuries ago.

In 1819, Colombia, guided by the powerful hand of the great patriot Bolivar, won her independence from Spain, and established herself as a republic. After many years of internal political dissensions, during

which the country bore successively the names "Republica de Colombia," "Republica de Nueva-Granada," "Estado Unidos de Colombia," a more settled organization was effected in 1885, the independence of separate states abolished, and the country again called the "Republica de Colombia," its present name. To-day Colombia is a single republican State, divided into departments, each department having a governor appointed by the central authority, and an elected legislative assembly.

The lines of communication between the Atlantic, or Caribbean, coast and the interior of the country are by the great river systems, chief among which is that of the Magdalena. The vast importance of the Magdalena River as a commercial highway will be seen at a glance on the map of its valley. This great river is navigable for 750 miles from its mouth by river steamboats of good size. Unfortunately for Colombia, the mouth of the Magdalena is rendered difficult for ocean steamships to enter by reason of the strong currents and shifting bars, and various unsatisfactory attempts to connect the river by an inland waterway with one of the coast harbors or bays made the necessity of a railway connection between the river and one or more coast ports imperative.

In 1880 there was completed and opened to the public service a short railway connecting the town of Barranquilla on the west bank of the river near its mouth, with the open Bay of Savanilla, a few miles west of the mouth. This railway was the property of the Colombian government, but its title passed to an English corporation which extended the railway to a more convenient terminus near the open end of the bay, and constructed a steel pier over 4,000 feet long in order to reach water sufficiently deep to permit steamships to lay alongside. The opening of this railway served to give to Barranquilla a commercial prominence heretofore held by Cartagena and Santa-Marta, both of which coast towns were connected by interior waterways with the river.

The magnificent harbor of Cartagena, rendered doubly secure by the artificial closing of its larger entrance, Boca Grande, by the Spaniards in the early days, had made of that city an ideal port, ranking among the six or seven finest in the world. The water route to the river, consisting partly of a natural delta of the Magdalena, or connecting chain of lagoons, and partly of an artificial canal designed by the eminent engineer Totten, was not sufficiently to be relied upon in

View of Cartagena, from San Felipe.

Street Scene, Cartagena.

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all seasons of the year to permit Cartagena to maintain its commercial supremacy in competition with the Barranquilla rail route to the coast. The unsatisfactory nature of the Bay of Savanilla as a harbor, it being an open roadstead, combined with the natural desire of the Colombian people to reëstablish Cartagena in its once prominent position, induced the government and people to urge the building of a railway to connect Cartagena directly with the river.

In 1890 and 1892, concessions were granted by the government of Colombia to Samuel B. McConnico, Esq., an American, giving him the right to build and operate such a railway, and to build and maintain wharves and warehouses at Cartagena, also giving certain exclusive privileges in connection with the rights for the term of fifty years. These concessions and rights were transferred to an American corporation, and the wharves, warehouses, and railway have been built, and a large fleet of river steamboats, operating in connection with the railway, has been placed upon the Magdalena River.

The object of this address to-night is to describe to you briefly the terminal works, railway and line of steamboats, owned and managed by an American corporation in Colombia. The railway and steamboat service taken together act as public carriers between Cartagena and points 800 miles in the interior, and represent an investment of about five million dollars American gold.

The concessions acquired by the American company include the exclusive privilege for a long term of years to maintain a service of lighters and tugs for the disembarking and embarking of cargoes, and for the construction and operation of wharves and terminal warehouses.

The company began active public business in 1891, handling the entire exports and imports of the port, using for the service two tugboats, one of English and one of American construction, and a fleet of lighters. This service continued until June 1, 1893, when the company's pier was completed, and the short terminal railway connecting the pier with the city proper opened to public service.

The pier is constructed of southern pitch pine, heavily creosoted for protection against the ravages of the teredo (*Teredo navalis*), and is 500 feet long by 120 feet wide, having a depth of water at the outer end of 40 feet, and a minimum depth alongside of from 29 to 30 feet. The material for the construction of this pier, the machinery used, and the skilled workmen employed, were all imported from the Gulf coast

of the United States. Extending nearly the whole length of the pier, and in its centre, is a warehouse 80 feet broad, part of which is used as a custom house, and part as a store for export goods. Upon each side of the pier between the warehouse and the water two lines of tracks are laid, and two lines run through the warehouse itself.

Imported goods are taken directly from the vessels' slings into the custom house and there, after examination and weighing, can be placed directly in the cars within the custom house itself. Export goods are discharged directly from the cars into the vessels' slings, or from the cars into the export section of the warehouse. At the inner end on one side of the pier is a special berth for colliers, with an elevated track and tram line to a conveniently placed depot for coals. Immediately adjoining the pier on the shore end, and connected with it by spur tracks, is the company's yard for the construction of steel river steamboats and lighters.

To this pier come regularly the steamships of the Royal Mail Steam Packet Company, the West-India & Pacific Steamship Company, the Harrison Line, the Compagnie Generale Transatlantique, the Hamburg-American Steam Packet Company, the Compañia Transatlantica de Barcelona, the Atlas Steamship Company, the Compañia Italiana, "La Veloce," and vessels of other but less regular lines.

The deep water of the harbor not extending to the city of Cartagena itself, it was necessary to place the pier at a point 1 kilometer from the city walls, and to connect the two by a railway. This short line of rails is laid for about two-thirds of its length across a mangrove swamp, and is solidly built on a causeway of corduroy topped with partially decomposed coral.

At the town end the line crosses an earth and stone wharf, or levee, placed just outside of the city wall, and connected with the city by two gates or ports, and upon the levee is a substantially built corrugated iron warehouse, local freight shed, offices, etc. To this levee, all, of course, under the control of the company, come to leave and take cargoes, the host of small 30- to 80-ton native-built coasting schooners, and the vessels of the coastal steamship companies. The pier, the short line of railway, the levee and warehouses, and the tugs and lighters make up the plant by means of which what is known as the "Terminal Service" of the company is performed.

It has been a matter of particular gratification to the directors of the company that the pier was so designed, both as to material and

An Inside Corner of the City Walls, Cartagena.

The Pier, Cartagena.

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method of construction, that it has shown no marked depreciation, either from the devouring worms, so prevalent in southern waters, or from the severe strains both of still and moving weights which have been constantly upon it.

While the terminal works were under construction, the work upon the main line of railway had been carried forward, and almost simultaneously with the opening of the pier service, the first section of the line, reaching from Cartagena to Turbaco, 24 kilometers (14½ miles), was formally opened to public service.

In making the preliminary surveys and final location of a railway line through a comparatively unsettled tropical country, no very great difficulties are necessarily encountered, but a multitude of small difficulties are almost certain to make vexatious delays. Notwithstanding the fact that Cartagena has been a place of importance for three and a half centuries, and that one-half the line of the Cartagena-Magdalena Railway follows closely the old highway or *Camino Real* of the *Conquistadores*, the only roads leading to the interior from Cartagena are rough mule trails, almost or quite impassable during the heavy rains. The absence of roads, and the thick, luxuriant, tropical vegetation made both the transportation of materials and supplies slow and laborious, and the use of instruments difficult. The inability of the younger engineers to speak Spanish added to the petty troubles of the engineering parties in the field.

After the preliminary work was finished, however, and the chief residencies established, *trochas* cut, mules and horses bought, and a definite organization adopted, the work of location and construction proceeded much as such work would in the United States, but less rapidly. With the exception of the trestle and bridge construction, and a certain amount of rock cuttings, the work was wholly performed by native laborers under the supervision of Americans or Europeans. The peasantry of Colombia, from whom the men employed were drawn, are the native full-blooded Indians and the various shades of Spanish cross-breeds. These men are, for the most part, well built and muscular, but irregular in their inclination for work, and loth to neglect for many consecutive days either the more congenial and less arduous task of field work in their own small plantain or maize plantations, or the welcome shade of their thatched huts. This natural irregularity is further increased by the great frequency of the days of *fiesta*, or Saints' days, which seriously interfere with all work in the Spanish-

American countries. In spite of generous wages offered, the labor problem was a troublesome one during the whole period of construction, and the number of men on the rolls seldom exceeded 1,200 to 1,600.

The length of the road from the pier at Cartagena to the terminus at Calamar, on the banks of the Magdalena River, is 106 kilometers (65 miles), the gauge 3 feet, and weight of rails 50 pounds to the meter. The cross-ties are placed 2,000 to the kilometer, or about 20 inches apart between centers. The maximum grade (made necessary in crossing over the Turbaco hills) is 2.5 per cent., and the sharpest curve has a radius of 478 feet. The highest elevation reached is 200 meters (656 feet) above the level of the sea, at kilometer 23 near Turbaco, and at Calamar, the river terminus, the elevation is but 8.5 meters (28 feet).[1]

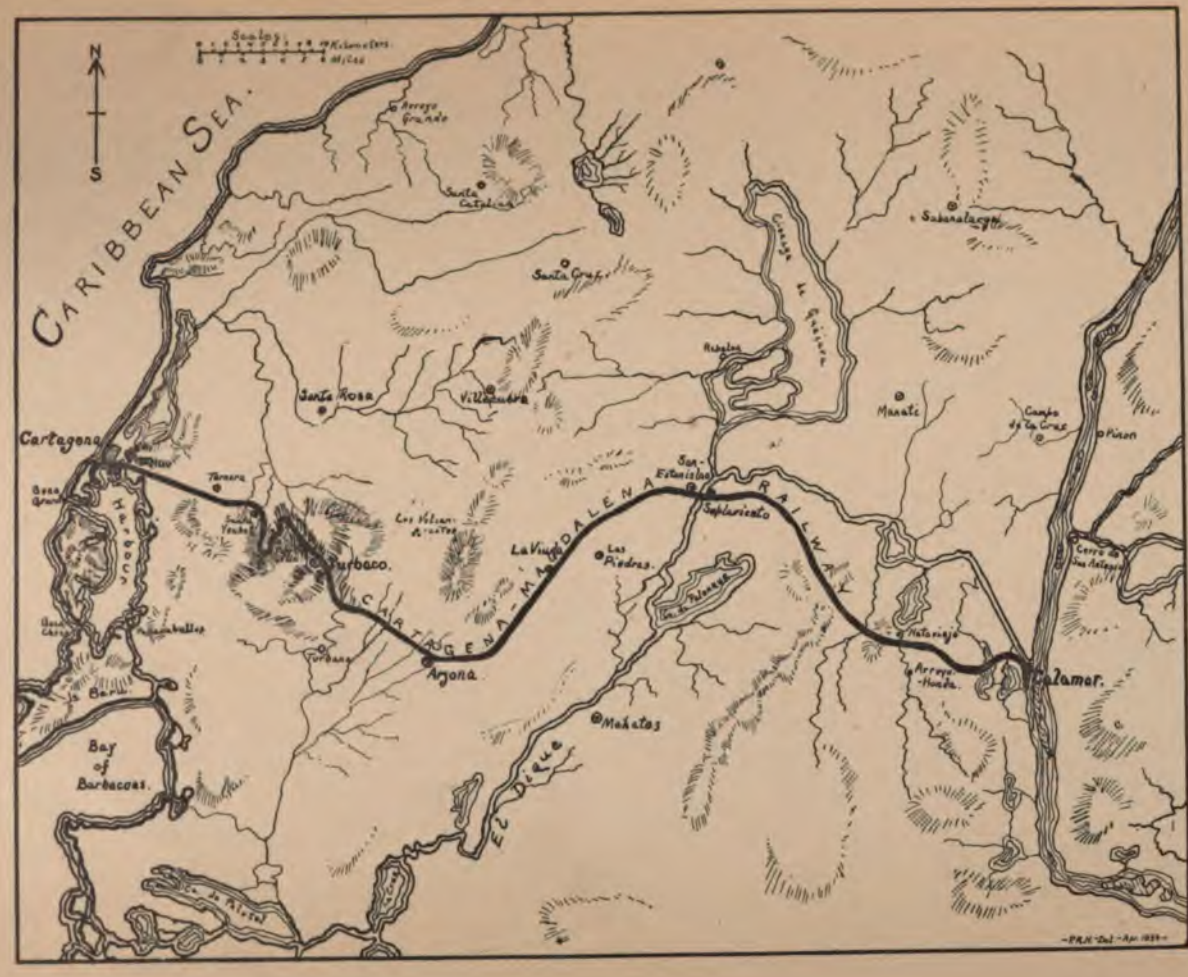
For crossing small streams, ravines, and lowlands subject to overflow, trestles of creosoted pitch pine were built, and the crossing of the Dique (the old waterway connecting Cartagena with the river) was effected by a steel bridge 120 feet long revolving on a central pier. The total amount of trestling was originally 3,358 meters (13,220 feet), but this is being reduced each year by the construction of permanent structures, culverts, etc.

The greater part of the cross-ties used were of fairly durable native woods, but the inability of the local contractors to deliver these sufficiently rapidly, made it necessary to import a certain quantity of American pine and cypress ties. Since the opening of the road, all tie renewals have been made with those of lignum-vitæ, which is so hard a wood that it is necessary to drill holes before the spikes can be driven, and which has a length of life hardly surpassed by the cross-ties of steel often used in tropical countries.

The permanent way is solidly built and well drained (the latter, perhaps, the most important quality of a good railway in the tropics), and withstands the heavy downpours of the rainy season in a manner which from the early experiences of the company's engineers during the construction period had seemed almost impossible.

The first section of the line is ballasted with decomposed or broken coral, and the appearance of the dazzling white roadbed and the lignum-vitæ cross-ties is sufficiently unusual to immediately attract the attention of the traveler from the north.

Along the line of the road are ten stations, with the necessary buildings, and at the termini are large warehouses, car sheds, shops,


CARIBBEAN SEA.
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S
Scale:
Arroyo Grande
Santa Catalina
Santa Cruz
Santa Rosa
Villanueva
Cartagena
Turbaco.
Arjona
La Viuda
Los Piedras
Mahatos
San Estanislao
Soplaviento
Mamate
Campo de la Cruz
Pinon
Calamar.
Bay of Barbacoas.
CARTAGENA-MAGDALENA RAILWAY
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CHARACTERISTICS OF ROAD.[1]

Name.	From	To		Length in kilometers.	Alignment.			Profile.							Bridges.		Water stations.
					Length of straight lines in kilometers.	Number of curves.	Aggregate length of curves in kilometers.	Length of level lines in kilometers.	Ascending Grades.			Descending Grades.			Class.	Total lengths in meters.	
									Number.	Sum of ascents in meters.	Length of ascents in kilometers.	Number.	Sum of descents in meters.	Lengths of descents in kilometers.			
Main Line	Cartagena.	Calamar.	Main Line.	105.602	77.892	139	27.710	31.146	44	391.96	35.053	37	383.91	39.403	Wooden trestles, Steel bridge.	2884.66 40.00	5
Main Line	Cartagena.	Calamar.	Sidings.	7.398													
Cartagena Terminal .	Cartagena.	Machina.	Main Line.	1.470	.984	3	.485	1.235	2	1.85	.235	—	—	—	Wooden trestles.	473.11	—
Cartagena Terminal .	Cartagena.	Machina.	Sidings.	2.358													

and other necessary buildings built chiefly of corrugated iron. At Cartagena on the broad Plaza de la Independencia is the principal station on the road, and the general offices of the company. This building is constructed of masonry, and is designed to conform architecturally with the principal buildings of Cartagena, and to provide cool and airy offices for the company's officers and employees.

The natural conditions governing the selection of materials and designs for buildings, water stations, etc., in the tropics differ from those influencing similar work in the north. No provision is necessary for snow or frost, but roofs and walls must be able to stand a force of rainfall never seen out of the tropics, and woodwork must be protected against rapid decay during the wet seasons. The white ants are even a more destructive enemy to wood than is the climate, and for this reason sooner or later, woodwork is almost certain to be replaced with masonry unless it is well above the ground. The picture showing one of the water tanks illustrates the most durable type of construction.

The equipment of the road is of the American type, and consists of four 40-ton Rhode Island 8-driver locomotives, three 20-ton Porter and one 25-ton Brooks 4-driver locomotives, and one 12-ton Porter switching engine. The passenger cars are of three types; first, second, and third classes, and the freight and cattle cars of the usual American form. It is, of course, particularly necessary for a railway so far from a base of general railway supplies to be more than usually self-contained in the way of stores and shop machinery, a fact which adds materially to the first cost and the expense of operation of isolated South American railways.

The road was opened to public service for its full length on the 1st of August, 1894, the formal opening having taken place with appropriate and impressive ceremonies on the 20th of July before, the anniversary of the independence of Colombia.

It is difficult to adequately describe the mental attitude of the peasants of the neighboring small towns towards a steam railroad, which in comparatively few months had been stretched across a country that for centuries had known no change. To them the engines were "horses of iron fed with fire," and in their simple language no other words could describe their ideas more accurately. Their curiosity and desire to ride in the strange conveyances were hardly sufficient to overcome the conservatism inbred by generations of unchanging cus-

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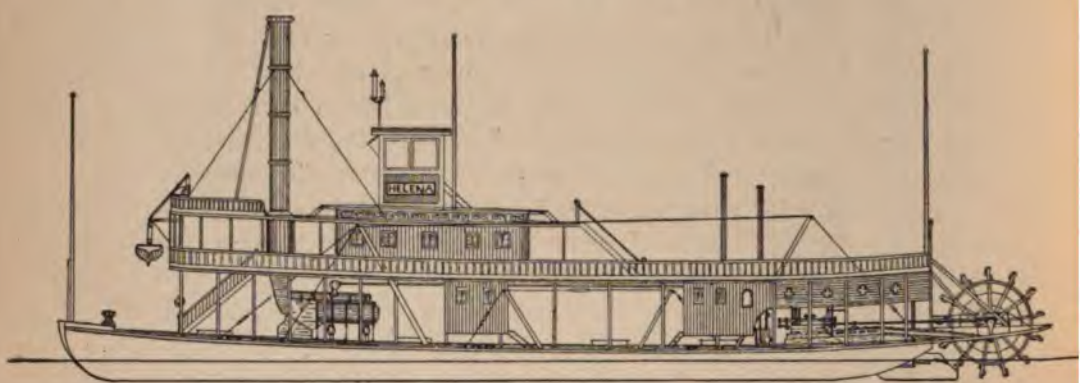
toms, and it has required both abnormally low rates and patient encouragement of small shippers to oust that powerful competitor of the South American railways, the overburdened *burro*, or donkey. Gradually, however, the local business along the line has developed, the cultivation of the neighboring territory increased, the *burro* competition ended, and Cartagena put in a position of dependence upon the railway for its daily supplies.

Except for a multitude of private and public cisterns the city is without any water supply system, and one of the daily tasks of the railway is to bring in water in tank cars. The number of passengers carried per year has averaged 60,000, about 15 per cent. of whom have been first-class passengers. The goods carried locally consist principally of market vegetables and supplies, Indian corn, tobacco, wood, grass, water, cattle, poultry, molasses for the distilleries, and imported manufactured merchandise for the country shopkeepers.

The "through" business, or traffic exchanged between the Magdalena River boats and the railway at Calamar, is of much more importance than the local business, and, owing to the establishment of a service of river boats under the same management as the railway, is rapidly increasing. The goods thus exchanged are the imported products of Europe and the United States purchased by the merchants of the interior towns and the exported products of the interior, consisting of coffee, tobacco, hides, ivory-nuts, cacao, cotton, minerals and specie. Coffee is the most valuable of the exported agricultural products, and tobacco the next. Goods for export are taken on through bills of lading from all the river ports to the pier at Cartagena, and *vice versa*. The movement of imported goods is facilitated by a rule of the custom house permitting the discharge of goods upon the filing of a bond and the payment of a percentage of the duties, the remainder being paid in due course by the consignees in the interior.

The staff of executive officers of the railway are American and English, as are also the chief employees, engine drivers, conductors, terminal superintendents, etc. The office accounting force is partly Colombian and partly foreign; brakemen and stokers are either Colombians or Jamaica negroes. The steamboat captains are either Colombians or foreigners who have resided a long time in the country; the pilots and other officers, and, of course, the crews, are all Colombians. The railway is operated by telegraph, all trains being controlled by the dispatcher at Cartagena, a maximum speed of 30 kilometers per hour

allowed, and an average running speed, including stops, of 26 kilometers per hour maintained. Both roadbed and engines are competent to sustain as high a speed as the average American railway, but the natural conditions have shown higher speeds to be unnecessary and less economical. On the railway imported coals are used exclusively for fuel, but the river steamboats use wood only. The language employed in the actual operation of the trains is English, but all other business of the company is conducted in Spanish, and nearly all of the principal employees speak both languages.



GENERAL DESIGN OF CARGO STEAMBOATS "ALICIA" AND "HELENA" OF THE COMPAÑIA FLUVIAL DE CARTAGENA.

Material: Steel. — Capacity: 300 tons. — Length: 165 feet. — Breadth; 33 feet. — Draught fully loaded: 4 feet. — Speed: 12 miles per hour. Builders: Jas. Rees & Sons Company, Pittsburg.

During the first few years of its operation, the railway suffered from the insufficient capacity of the line of steamboats connecting with the railway at Calamar, and a company was finally organized to undertake that part of the business. The new company, the Compañia Fluvial de Cartagena, put its first boat upon the river a little more than a year ago, and since that time has purchased the fleet of the former contracting company, and added to its own until it has twelve boats in operation. These boats are all built of steel, and have been received in parts from England, Germany or the United States, and constructed at Cartagena. Six of the boats are of 300 tons burthen, or over, and six of them of a lesser size. With the exception of two of the smaller, the boats are all of the stern-paddle-wheel type, a familiar sight on the western and southern rivers of the United States. Those

On the Magdalena River.

Town of Magangué, Magdalena River.

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of English, German and American construction are very nearly alike in design, but the engines of the American boats are of the simple high-pressure, non-condensing type, while those on the English and German boats are either compound or triple-expansion condensing engines. No more satisfactory style of boat, both as to general design and machinery, has been found than those built at Pittsburgh, one of which is shown in the accompanying sketch and illustration.[1]

The service performed by the boats can be readily understood from the map of the Magdalena Valley. This service is divided into two parts, the most important being that between Calamar and ports up to and including Dorada, between which ports regular trips are made every few days. At Dorada connection is made with a short railway which transports goods and passengers around the rapids near Honda. These rapids are not navigable in the ordinary sense of the word, although with the assistance of powerful steam winches and cables fastened to the banks, the steamboats necessary for the service above the rapids are more or less easily conveyed thither.

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[1] The approximate specifications of these boats are as follows:

Length, 145′ on deck; beam, 33′; depth of hold, 4′ 6″.

Floor frames, angle steel 2″ x 3″, 18″ apart.

Deck beams of angle steel, 3′ apart, except forward, where for strength they are much nearer.

Plating. Open hearth steel, galvanized. Keel plates, 7 pounds to the square foot. Bow and angle plates and exposed parts, 8 pounds to the square foot. Top plates on sides and bottom, 6 pounds to the square foot. Seams and butts double rivetted.

Bulkheads. One center and two wings, fore and aft, of Nos. 10 and 12 wire gauge steel, stiffened with angle iron uprights, and bulkhead plates rivetted to bottom plating. Compartments made as water-tight as possible.

Cross bulkheads. Five of steel, No. 12 wire gauge.

Keelsons. One longitudinal on each side, of 3″ Z bars.

A breast hook forward stiffens the bow, strengthening the supports for capstan and nigger engine, bitts, etc.

Engine beams. Angle iron and steel plating, well secured.

Transom. Angle iron and steel plating, strongly made for supporting engine beams and rudder.

Decking. ⅛″ iron plating, galvanized.

Rudders. Three balance rudders, with stocks and tillers of wood.

Hog-chains. One set on each side of 1½″ steel rods. One set on each side of smaller relief chains. One set of chains and braces suspending wheel support.

Cabin frame, upper deck, etc. Composite wood and iron.

Engines. One pair high-pressure engines, 15″ diameter of cylinders and 6′ stroke.

Boilers. Horizontal, cylindrical tubular type, 3½″ tubes, tested to 225 pounds, and intended for working pressure of 160 pounds. Fire-boxes arranged for wood fuel.

From the terminus of the Ferrocarril de la Dorada, just above Honda, a steamboat service is maintained with ports up to 150 miles further up the river, or about 750 miles from the river's mouth.

Upon the Lebrija and Sogomoso rivers, tributaries to the Magdalena, the steamboat company operates a supplementary service of small steamboats in connection with their main line of boats. About 40 per cent. of the total goods handled upon the river passes through Honda, either by being exchanged between the lower and upper river boats, or by being brought or taken away by the trains of mules constantly on the road between the capital, Bogotá, and Honda. The quick dispatch and safety of goods carried by the boats and railway is in sharp contrast with the transportation of the same goods in the interior. It is not an uncommon sight to see thousands of bales of goods lying on the banks, unprotected from the drenching rains, and awaiting nothing better than a rough trip on the back of a mule for many days, or a moist voyage up some small stream in a leaky canoe.

Nearly all of the river boats are fitted with adequate passenger accommodations, and the voyage from Calamar to the head of navigation and return can be made not only with comfort and pleasure, but is full of interest and novelty. In time it may be appreciated by the American people that within a comparatively few hundred miles from their own coast, and easily reached by comfortable steamships from New York, is a country awaiting and inviting their exploration. Perhaps the newly awakened interest in things West-Indian and Spanish-American may turn our winter pleasure-seekers southward, and make of the Magdalena another Nile. Cartagena, with its ancient walls and fortresses, its palace of the Inquisition and underground passages, and its historical associations with the days of conquest and piracy, can well claim equality with many an old world tourists' haunt in point of interest. In appearance little has changed in the town since those early days, but commerce has taken the place of plunder in sustaining the city, and its water front and warehouses are resonant with the hum of trade where once was the rattle of musketry and the grinding of steel.

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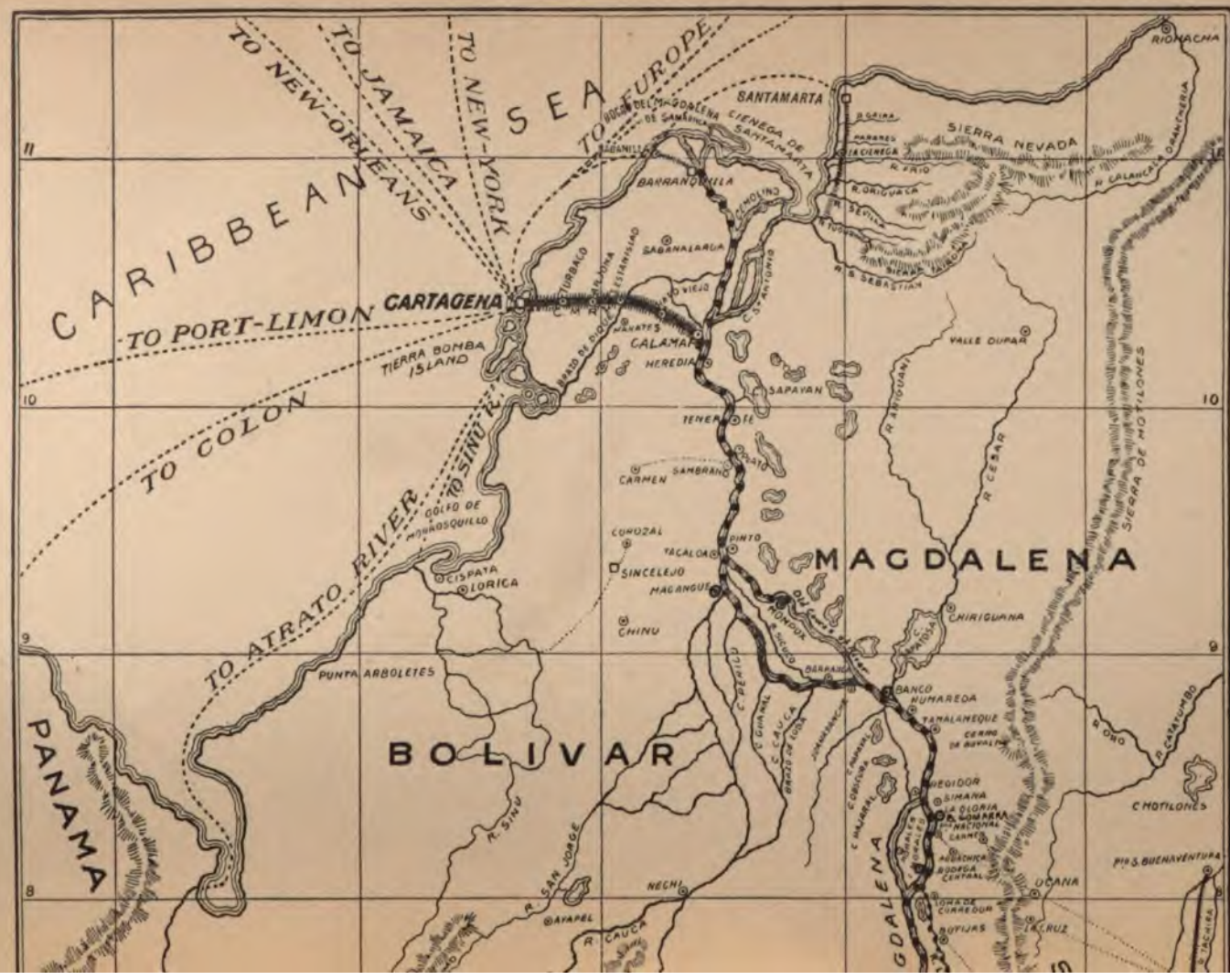
CARIBBEAN SEA
TO NEW-ORLEANS
TO JAMAICA
TO NEW-YORK
TO EUROPE
TO PORT-LIMON
TO COLON
TO ATRATO RIVER
TO SINU R.
CARTAGENA
TIERRA BOMBA ISLAND
GOLFO DE MORROSQUILLO
CISPATA
LORICA
PUNTA ARBOLETES
BOLIVAR
PANAMA
MAGDALENA
SANTAMARTA
CIENEGA DE SANTAMARTA
SIERRA NEVADA
RIOHACHA
BARRANQUILLA
SABANALARGA
CALAMAR
HEREDIA
SAPAYAN
TENERIFE
OCAÑA
CARMEN
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BARRANCA
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HUMAREDA
TAMALAMEQUE
CHIRIGUANA
VALLE DUPAR
R. ARIGUANI
R. CESAR
SIERRA DE MOTILONES
R. ONO
R. CARBUNUBO
C. MOTILONES
Pto. S. BUENAVENTURA
UCANA
LA CRUZ
ROTUJAS
NECHI
AYAPEL
R. SAN JORGE
R. SINU
R. CAUCA
R. MAGDALENA
R. SEVILLA
R. FRIO
R. ORIGUACA
R. SAN SEBASTIAN
R. CALANCALA
GRANCERIA
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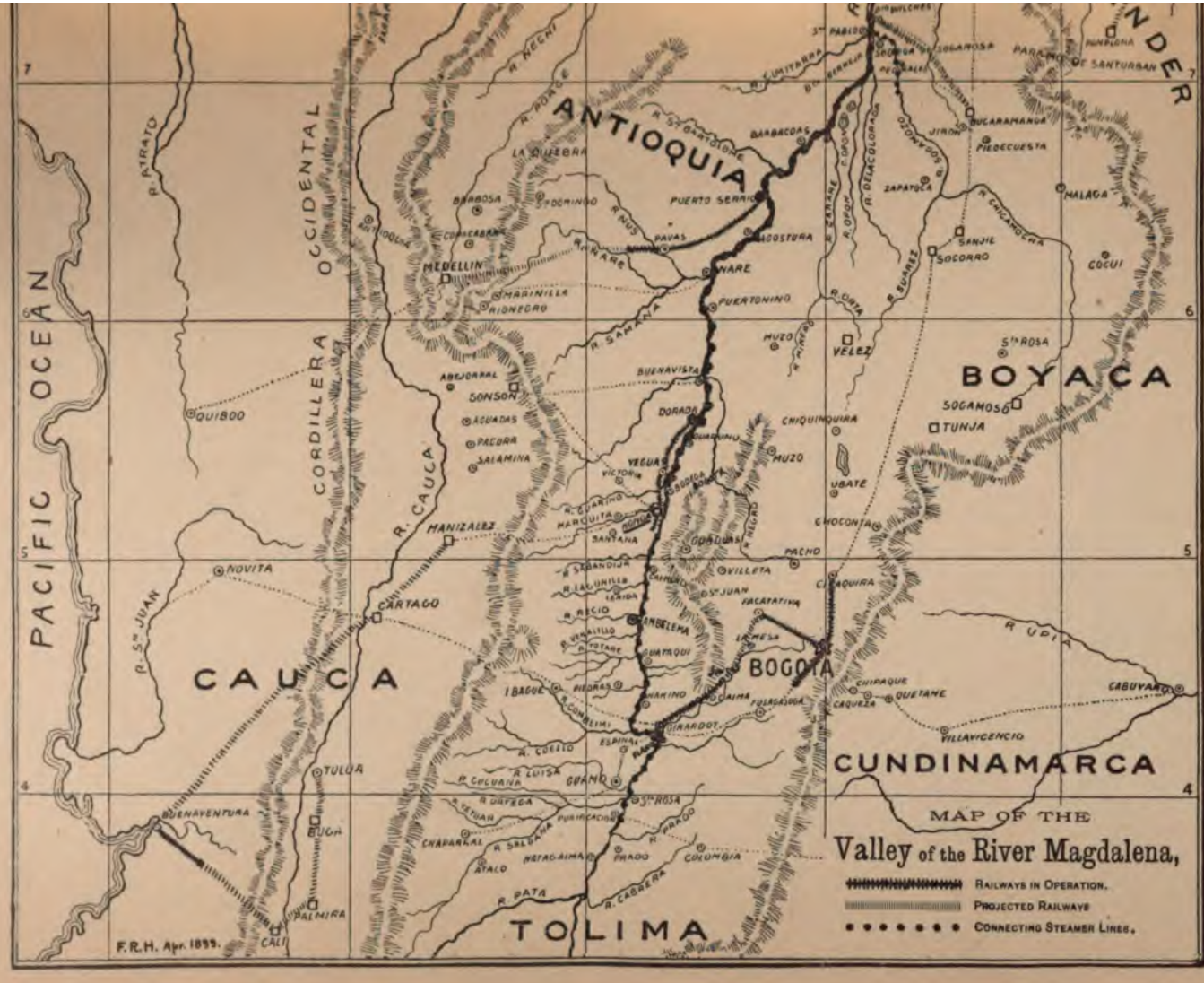
MAP OF THE
Valley of the River Magdalena,
RAILWAYS IN OPERATION.
PROJECTED RAILWAYS
CONNECTING STEAMER LINES.
PACIFIC OCEAN
CORDILLERA OCCIDENTAL
ANTIOQUIA
BOYACA
CAUCA
BOGOTA
CUNDINAMARCA
TOLIMA
MEDELLIN
MANIZALEZ
CARTAGO
BUENAVENTURA
PALMIRA
CALI
TULUA
BUGA
NOVITA
QUIBDO
PUERTO SERRANO
PUERTONINO
BUENAVISTA
DORADA
VEGUAS
MARQUITA
SANTANA
GUADUAS
VILLETA
BELEMA
FACATATIVA
BOGOTA
CHIQUINQUIRA
MUZO
VELEZ
UBATE
CHOCONTA
PACHO
SOGAMOSO
TUNJA
SOCORRO
SAN JUAN
MALAGA
COCUI
BUCARAMANGA
PAMPLONA
PARAMO DE SANTURBAN
CABUYARO
VILLAVICENCIO
QUETAME
CHIPAQUE
CAQUEZA
IBAGUE
HONDA
GUAMO
ESPINAL
FLANDES
PRADO
COLOMBIA
CHAPARRAL
AYALO
NATAGAIMA
PURIFICACION
SALDAÑA
GUAYABAL
ZAPATOCA
PIEDECUESTA
JIRON
SOGAMOSO
SANTA ROSA
SONSON
ABEJORRAL
ACUADAS
PACORA
SALAMINA
RIONEGRO
MARINILLA
BARBOSA
CONCEPCION
BARBACOAS
LA QUIEBRA
R. CAUCA
R. NECHI
R. PORCE
R. NUS
R. NARE
R. SAMANA
R. GUARINO
R. SAN JUAN
R. DIA
R. CUCUANA
R. COELLO
R. LUISA
R. ORFEGA
R. SALDAÑA
R. PATA
R. CABRERA
R. UPIA
R. SUAREZ
R. CHICAMOCHA
R. OPON
R. DE LA COLORADA
R. LIMITARNA
R. SAN BARTOLOME
R. ARANCE
R. ORTA
R. PAMPLONA
R. ATRATO
R. SAN JUAN
F.R.H. Apr. 1899.

THE GEODETIC OBSERVATORY AT MIDDLESEX FELLS.

By GEORGE L. HOSMER.

Read April 13, 1899.

THE present year marks a radical change in the course of instruction in geodesy at the Institute. The occasion is the completion of a geodetic observatory at Middlesex Fells, where instruction is now given in astronomical observations such as will prepare students for the career of observer in geodetic work. This new feature of the course is the result of the efforts of Professor A. E. Burton to establish a laboratory where geodetic measurements may be made. The introduction of work of this character into the course gives the student an insight into the practical side of geodetic operations, and it creates an interest in the subject and gives a reality to it which class work alone could never do. It will enable the Institute to send out men who have that confidence in their own power which laboratory work of the right kind is able to give.

This observatory is not so general in character as an "astronomical observatory," but confines itself to such observations as have a direct bearing on geodetic work. It corresponds very nearly to the regular astronomical station of the Coast and Geodetic Survey, the chief difference being that it is of a more permanent character. An astronomical station may be defined as a point whose exact position on the earth's surface has been determined (astronomically), and where any data needed in geodetic operations have been obtained. These stations serve two purposes: First, they are of primary importance in the solution of the problems of geodesy, and have, therefore, a use of a purely scientific nature. Second, they have a practical application in geodetic surveying. The character of the observations is in either case the same, namely, the location of the point upon the earth's surface, and finding the direction of some line of the survey. At this observatory all of the observations are of this character, and all are concerned with geodetic operations.

The part which the astronomical station plays in these problems may be better understood if we inquire a little more closely into the nature of the problems themselves. In the first case before mentioned,

the object of geodetic operations is the determination of the size and figure of the earth. By the "figure of the earth" we may mean either the form of the actual surface with all its irregularities, or the form of some simple mathematical surface which is a close approximation to the true figure. For most purposes it is only this fictitious surface which we can use, and the closeness with which this surface approaches the true one must depend largely upon the application we intend to make of it. For nearly all purposes the oblate spheroid is the adopted figure. The true figure of the earth is found by determining the local deviations of the surface from this imaginary spheroid. The problem of finding the earth's form is, therefore, divided into two distinct parts, the determination of the simple mathematical surface best representing the true figure, and the study of the true figure by comparison with this fictitious surface.

For the purpose of obtaining the elements of the spheroid it is necessary to combine measurements of arcs of a meridian with measurements of the latitudes of the extremities of these arcs. In other words, we must compare the lengths of arcs on the surface with the angles they subtend in order to know the form of the meridian ellipse. The work of measuring the length of an arc belongs to the field work of geodesy, and is not directly concerned with the astronomical observations. The second part of the arc measurement requires that astronomical stations should be established at the north and south extremities of the arc. Here we must determine with extreme accuracy the latitudes and longitudes of these points. This determination of the position is the most important set of measurements made at the point, but the station also serves other purposes, as will be seen later on. The measurement of a number of such arcs (theoretically two) will determine the form and size of a spheroid which will be a general average of all parts of the surface covered by the measurements.

Having obtained the representative figure, our next step is to find where and how much it differs from the earth's true figure. The astronomical station affords a means of making these measurements. First, it must be observed that our determination of the astronomical position depends directly upon the direction of gravity, since it is only by means of a spirit-level or a plumb-line that we can determine that important point of reference, the zenith. Second, any change in the direction of the surface produces a change in the direction of gravity. If this change is not in accordance with the change in a spheroidal

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Z S P I N A L
V E N E D

PLAN
OF THE
CITY OF CARTAGENA
SHOWING THE LOCATION OF THE
TRACKS, BUILDINGS AND WHARVES
OF THE
CARTAGENA TERMINAL & IMPROVEMENT CO. LD.,
AND CARTAGENA-MAGDALENA RAILWAY CO.

THE N[illegible]K
PU[illegible]7.

[illegible]OX AND
[illegible]IONS.

surface, there will be a "local deflection of the plumb-line" at that point; the vertical line will be different from what it would on the spheroidal surface. This difference is known as "station error." The magnitude of the "station error" is obtained as follows: Astronomical stations are taken in groups and connected by a triangulation survey. This triangulation enables us to compute the position of one point from another. Now by reducing all of the observed positions to one station and taking the mean of the results, we get a position nearly what it would be if the surface were truly spheroidal. By reversing our computation we may find such a position for each station. These computed positions show the direction of the vertical on a spheroid, while the observed position shows the direction of the vertical on the "geoid." The difference at any station is the "station error" for that point. It is never more than a few seconds. Such comparisons as these taken over all parts of the surface would enable us to find the true figure of the earth.

This problem may also be solved by means of the pendulum, and this is becoming an extremely important method in geodesy. The variations in the force of gravity show the variations in the distance to the center of the earth; hence a measurement of this quantity at known points will enable us to find the earth's figure. The measurement of the force of gravity by swinging a pendulum requires an accurate knowledge of the rate of the timepiece used in getting the time of an oscillation. Furthermore, the observation is of little value unless its exact position upon the earth's surface be known. Hence it is almost a necessity that the astronomical station and the pendulum station should be at the same point.

So much for the use of the astronomical station in the problem of finding the earth's figure. Having found the size and form, we now come to the application of this knowledge to a practical end. Our problem is to carry on a survey over an area so extensive that it becomes necessary to take into account the curvature of the surface. In its application to geodetic surveying the astronomical station again finds two uses. Any network of triangles used in the survey of a large area must be located upon the spheroid before calculations can be made; *i. e.*, it is necessary to know just what part of the spheroid we are using. Furthermore, astronomical location serves as a check upon the triangulation, for while the latter is far more accurate than the former for short distances, it is not so for long ones. The accu-

racy of astronomical location is nearly the same for all parts of the surface, while the errors of triangulation accumulate with distance.

From the foregoing it will be seen that the immediate problems of the astronomical station are the exact determination of latitude, longitude, time, and azimuth, as well as the force of gravity, and incidentally the magnetic elements. As these measurements are all of the most precise character, it is necessary, in order to secure the desired degree of accuracy, that the work be done under the most favorable conditions, and success will depend largely upon the care and skill exercised in selecting the site of the station, and in the arrangement of the details of the building. It is essential that the ground should be free from vibrations such as would be caused by railway trains or heavy teams. The surrounding air must be free from the smoke and light of the city; if magnetic work is to be done, anything tending to cause magnetic disturbances must be avoided; and since the point is to be connected with the surrounding triangulation, it ought to be visible from well established triangulation stations. For this reason it is usually on elevated ground. The building need not be a large one, but sufficient to enable the observer to work conveniently about his instruments, and to afford the proper shelter. The instrument must be mounted upon a firm support, usually a stone or brick pier, which must be entirely separated from the floor of the building, as the slightest jar is sure to be communicated to the instrument. The spot ought to be selected with regard to its permanence, for the location is of value and might be of great service in any future work of a similar character. From these considerations it would seem that a public reservation, where there is little danger of the points being disturbed, and where railroads and heavy teams are likely to be kept at a considerable distance, would offer a good location. If, in addition, the point can be selected so as to be visible from important triangulation points, and is free from magnetic disturbances, it fulfills all of the requirements of a good station.

When it was proposed that an observatory should be built by the Civil Engineering Department of the Institute, a careful study was made of the public parks near Boston to find a spot which fulfilled as many as possible of the above named conditions. The spot that was selected is unusually well suited to the purpose, for it not only satisfies the necessary conditions, but has the additional advantage of being comparatively near the other buildings of the school. The site of the

FIG. 1. — THE GEODETIC OBSERVATORY.

FIG. 2. — THE INTERIOR OF THE OBSERVATORY WITH THE INSTRUMENTS IN POSITION.

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observatory is in the southeastern portion of Middlesex Fells, about one mile from the city of Malden. The nearest point on the railroad is at a distance of two-thirds of a mile, and the nearest highway is over a quarter of a mile away. The nearest park road (where only light travel is allowed) is 460 feet distant. There is little danger under these circumstances that much trouble will be caused by vibrations. The atmosphere is very clear, on account of the elevation of the point and its distance from all settled districts; this is a condition which could not be reached near a city. In regard to magnetic disturbances the spot is well chosen. The nearest electric current is one-quarter of a mile away, and moving masses of iron such as carriages and bicycles cannot approach nearer than about 460 feet. This is a condition not easy to obtain in combination with so many other advantages. The number of triangulation points visible is quite large, including Blue Hill, Prospect Hill, State House, Nahant, Powderhorn, Tufts College, and Bear Hill. These are all important points in the Massachusetts system of triangulation, and make it easy to determine the position of the observatory very accurately. The building itself is about 15 feet square, and is built of the field stone found in the vicinity. It is set upon an outcropping ledge whose elevation is about 290 feet above mean tide. There is a clear horizon in nearly all directions. In the roof of the building is a slit about 14 inches wide extending in the north and south direction. The pier on which the instrument is mounted is placed directly underneath this opening. It is set directly upon the ledge, and built up to a height of about 3 feet above the floor. It is made of brick, and is capped with a stone about $2\frac{1}{2}$ feet square and 4 inches thick. The instrument is mounted so as to swing in the plane of the meridian. The opening in the roof is extended down the walls to about the level of the top of the pier, so that any portion of the meridian (above the horizon) may be seen. By placing the pier a little out of the central position, it was found possible to see Blue Hill and Prospect, through the windows from the pier, thus avoiding an eccentric station in locating the point by triangulation.

The instrumental outfit consists of a $2\frac{1}{2}$-inch portable transit instrument provided with a micrometer and a level for latitude observations, a chronometer and a chronograph. With these instruments latitude, time, and longitude observations may be made. Beside these there is a complete magnetic outfit (*i. e.*, a magnetometer and a dip circle), and an alt-azimuth instrument with circles reading to seconds by

means of microscopes. A pendulum apparatus is now being made for this observatory. These instruments, together with several smaller ones, make up an outfit with which all of the observations necessary in geodetic work can be made. With this equipment the students of geodesy have been carrying on a regular series of observations for latitude, time, and longitude. The latitude observations have been made both with the zenith telescope and the vertical circle. The two sets of results show a close agreement. In the longitude work the method of moon culminations has been used chiefly. A little later this observatory will have a wire from one of the telegraph offices, so that it may be connected with other observatories, and its longitude very accurately found by the "telegraphic method."

A brief description of the method of making and recording these observations may not be out of place here. The transit instrument, with which the time observations are made, is mounted so as to revolve in the plane of the meridian. In the "field" of the telescope are five vertical threads (spider threads stretched across a metal ring). These are spaced so that a star at the equator travels from one thread to the next in about twelve seconds. The observation consists in noting the time that the star crosses each thread and recording it. After the proper instrumental corrections are applied to these times the result is a measurement of the local sidereal time at the instant of the observations, and shows the error of the chronometer. The method of recording is that known as the "American method," *i. e.*, by chronograph. The essential parts of the instrument are a revolving cylinder carrying a sheet of paper, and a pen, in contact with the paper, moving along an element of the cylinder. The two motions cause a spiral line to be traced on the sheet. The pen is attached to the armature of an electro-magnet, the coils of which are connected with a chronometer, a key, and a battery. This chronometer is arranged to break the circuit at regular intervals (two seconds), thus causing the pen to move sidewise and make a notch on the sheet. In this way the sheet is graduated into minutes and seconds of the chronometer time. When the observer wishes to record the instant that a star crosses a thread, he presses the key, and makes a notch on the paper between two of those made by the chronometer. The position of this notch is easily measured, and the corresponding time known within about a hundredth of a second. If the transit of the moon be included in the set of observations on stars, its position at the instant can be found; a com-

parison with the (known) Greenwich time when it had the same position gives the longitude of the place of observation. But a far more accurate way of finding longitude is by telegraph. The main line is so connected that records can be made at the same instant on chronographs at each end of the line. In this way the local times of the two places are directly compared so that the difference of longitude becomes known. Observations for latitude are most accurately made by the zenith telescope. The accuracy of the method depends upon the fact that the measurements are all differential. Such measurements are more easily and more accurately made than absolute values. Stars are selected in pairs, one north and one south of the zenith, and at nearly equal distance from it. A micrometer serves to measure the small difference of the zenith distances, while a spirit level shows the amount the telescope has moved between the two measurements. From these measures the latitude is easily deduced. The latitude of the observatory has also been found by measuring altitudes of the pole star, by means of an alt-azimuth instrument and a basis of mercury. These two independent determinations check each other very closely. These descriptions merely serve to show what kind of observations are being made and do not go into details. All of these methods are very fully explained in various reports and text-books. Examples of time and latitude observations are given at the end of this paper.

A considerable amount of work has been done here this year which has never before been possible at any of the Institute buildings, such, for example, as tests of delicate spirit levels, tests of pivots, etc. This is also quite true of the magnetic work. None of the observations previously made could be regarded as really valuable; all that was attempted was to teach the methods. At this place there is practically no local disturbance, and the observations ought to be trustworthy. In all of this work it is the aim to get reliable results, so that the student is actually observing, and not merely going through the manipulation in order to learn it. The work offers a large variety of problems, and the student is continually working at something new. He is thrown upon his own resources and held responsible for his results, just as he will be in his later experience. In this way he is trained to attack new problems, and is kept constantly on the watch for causes tending to affect the accuracy of his results.

The work that has been done this year is only a beginning, but it is a beginning under favorable conditions. When the latitude and

longitude have been accurately determined and the position connected with the neighboring survey points, this observatory will become an important station in the Massachusetts system of triangulation. The location is an excellent one, and has everything in its favor for accurate work, so that the outlook for the future is very encouraging.

Following are the records of two sets of observations made at the observatory, given in order to show the kind of observations and the method of working them up. These are very nearly the same as those of the Coast Survey and other similar surveys, so that no special explanation will be necessary.

TABLE I. TRANSIT RECORD.

Station, Middlesex Fells. Date, November 15, 1898. Chronometer, Bond 541.

π Pegasi.	7 Lacertæ.	10 Lacertæ.	ι Cephei.	π Cephei.	Br. 3077	τ Pegasi.	ι Androm.
Clamp E.	E.	E.	E.	W.	W.	W.	W.
32.0 56.0 62.5 26.0 94.5 82.0 82.0 12.5	12.5 15.0 27.5 13.75 × .0092 − .02 = + 0.11	48.5 39.0 46.0 40.5 94.5 79.5 79.5 15.0	Temp. = 45° F.	59.0 30.0 41.0 48.0 100.0 78.0 78.0 22.0	22.0 9.0 31.0 15.5 × .0092 + .02 = + .16	32.0 56.0 61.0 28.0 93.0 84.0 84.0 9.0	Temp. 43° F.
	b_w = + 0.11				b_w = + .16		
22 03 42.10	25 10.71	32 53.50	43 45.90	23 01 46.64	06 21.74	13 53.08	31 19.15
56.79	29.95	33 09.41	44 15.82	02 34.00	43.82	14 06.64	35.84
71.45	48.85	25.12	——	03 21.63	07 06.40	20.15	52.30
86.10	08.42	——	45 15.85	04 08.95	28.67	33.70	69.52
100.96	27.25	57.05	45.82	04 56.00	51.40	47.10	86.42
22 03 71.48	25 49.04	33 25.23	44 45.87	23 03 21.44	07 06.41	14 20.13	31 52.65
− .02	− .02	− .02	− .04	− .06	− .03	− .02	− .02
+ .13	+ .17	+ .14	+ .25	+ .52	+ .28	+ .16	+ .22
− .03	− .01	− .01	.00	+ .01	+ .01	+ .01	+ .02
04 11.56	25 49.18	33 25.34	44 46.08	03 21.91	07 06.67	14 20.28	31 52.87
05 30.65	27 08.45	34 44.50	46 05.99	04 42.76	08 26 16	15 39.26	33 12.14
1 19.09	1 19.27	1 19.16	1 19.91	1 20.85	1 19.49	1 18.98	1 19.27

NOTE. — Value 1 div. level = 0.″55. Hourly rate = + .033. Pivot inequality + .02. A dash indicates that the thread was missed.

TABLE II. REDUCTION OF TIME OBSERVATIONS.

	Star.	Pos.	$a-t$.	C.	A.	Cc.	Aa.	ΔT $a-t-Cc-Aa$.	v.	
			m. s.							
	π Pegasi	E	+1 19.09	−1.19	+ .20	−.02	− .15	19.26	.04	
	7 Lacertæ	E	19.27	−1.55	− .20	−.02	+ .15	19.14	.08	
	10 Lacertæ	E	19.16	−1.28	+ .09	−.02	− .07	19.25	.03	
	ι Cephei	E	19.91	−2.43	− .96	−.03	+ .72	19.22	.00	$\Delta T = +$ m. s. 1 19.21.
										h. m.
	π Cephei	W	20.85	3.82	−2.05	+.05	+ .160	19.20	.00	at 22 52.
	Br 3077	W	19.49	1.81	− .44	+.03	+ .34	19.12	.08	
	τ Pegasi	W	18.98	1.09	+ .36	+.02	− .28	19.24	.04	
	ι Androm	W	19.27	1.36	− .01	+.02	+ .01	19.24	.04	
			$a-t$.	C.	A.	Cc.	$a-t-Cc$.	Aa.	$a-t-Cc-Aa$.	$c=+.029$
1st approx.	Mean of time stars	E	19.17	−1.34	+ .03	−.04	19.21	− .02	19.23	$a_e=-.78$
1st approx.	Az. star	E	19.91	−2.43	− .96	−.07	19.98	+ .75	19.23	$a_w=-.76$
1st approx.	Mean of time stars	W	19.25	1.42	− .03	+.04	19.21	+ .02	19.19	
1st approx.	Az. star	W	20.85	3.82	−2.05	+.11	20.74	+1.56	19.18	
2d approx.						−.02	19.19	− .02	19.21	$c=+.014$
2d approx.						−.03	19.94	+ .73	19.21	
2d approx.						+.02	19.23	+ .02	19.21	$a_e=-.755$
2d approx.						+.05	20.80	+1.60	19.20	$a_w=-.778$

TABLE III. LATITUDE RECORD.

Middlesex Fells. December 7, 1898. Temple transit.

STAR.	Mag.	Z. D.	N. or S.	Chr. time.	Microm.	LEVEL. N.	LEVEL. S.	REMARKS.
		° ′		h. m.				
τ Pegasi . .	4.6	19 16	S.	23 13	18.075	17.2	90.8	Temp. 37° F. Lev. "O" toward eye piece. E. P. for microm.
4 Cassiop .	5.8	19 16	N.	18	17.027	85.5	11.3	

$\frac{1}{2}(\delta_s + \delta_n$	42° 27′ 47″.00	t 1.048	90.8
			17.2
$\frac{1}{2}(Z_s - Z_n)$	— 1′ 21″.64	log 0.02036	108.0
	42° 26′ 25″.36	$l.\ r.$ 2.19257	54.0
$\frac{1}{2}(l_n - l_s)$	+ 2.80	2.21293	
	42° 26′ 28″.16	163″.28	85.5
			11.3
$\frac{1}{2}(r_s - r_n)$	— 0.03	2′ 43′.28	96.8
$\varphi =$	42° 26′ 28″.13	1′ 21″.64	48.4

ON RAPID METHODS FOR THE ESTIMATION OF THE WEIGHT OF SUSPENDED MATTERS IN TURBID WATERS.

By CHARLES L. PARMELEE and JOSEPH W. ELLMS.

PROBABLY the most notable characteristic of the surface waters of the central and western portions of the United States is the great variation in the character and amount of the suspended matters which they contain. In the purification of such waters the removal of the suspended matters is a very important factor, not only from an absolute point of view, but also from the influence which they exert upon the various steps in processes of purification. On this account reliable information as to the amount of suspended matters present in the water to be purified is very essential, in order to adjust properly the several steps in the process that the water may be handled in the most efficient and economical manner. This information should be readily and quickly available; in fact, unless it is so, its value is lost, save as a matter of record upon which future judgment may be based.

So far there has been satisfactorily developed no better means of measuring the amount of suspended matters present in water than by determinations of its weight, volumetric measurements not being sufficiently accurate. The determination of the weight of suspended matters in water, dealing as it does with comparatively small amounts of solid material distributed through large volumes of water, involves difficulties which are not apparent in any hasty consideration of the subject. These difficulties are considered in detail in the following section.

GRAVIMETRIC DETERMINATION.

The gravimetric method consists in weighing the residue left after evaporation of a given volume of the water and also the residue from an equal volume of the same water after being filtered, in order to obtain the weight of the dissolved constituents. The difference between the two weights represents the weight of the suspended matters. This is the only direct means of measuring the weight of

suspended matters. Any other method should be compared with this as a standard, and in the formulation of laws and abstract relations, reliance should be placed on the gravimetric determination as a basis. This method is too time-consuming to fulfill satisfactorily the requirements outlined above, and this paper contains descriptions of certain rapid methods for the estimation of the weight of suspended matters, which the writers have studied with considerable care, and which are apparently sufficiently applicable under the conditions described to warrant their presentation.

In any scientific study one of the first constants to be determined is that of the base of reference. Absolutely speaking, nearly all standards are somewhat in error, and in the case in hand the standard of reference, the gravimetric determination, is liable to errors of considerable magnitude. These are as follows:

1. Imperfect drying of the residue after evaporation of the water. Under the best conditions this error is very low in amount, and it should never exceed $\pm$ 2 parts per million.

2. Absorption of moisture after drying and preceding and during weighing. Under normal conditions of the atmosphere this is not a large factor, but with high humidities samples have been known to gain in weight from 5 to 20 parts per million even during rapid and skillful manipulation.

3. Variations in the action of the filter on the dissolved materials in the water.

Normally Nos. 1 and 2 are very low, and with the best apparatus and careful work they can usually be kept below amounts of serious magnitude; but the variations in the effect of the filter on the dissolved constituents in the sample do not seem to be controllable within a range of $\pm$ 5 parts. In the filtration of waters containing large amounts of very finely divided clay, filter paper is totally inadequate, and a Pasteur filter tube is used. These tubes at times seem to retain to a varying degree dissolved materials from the samples, and at other times these materials seem to be given up to the water passing through the tube.

It will, therefore, be seen that the gravimetric determination, which is our standard of precision, is at all times in doubt by at least 5, and perhaps 10 parts, plus or minus. To a certain extent these errors may balance each other in any one sample, and in a series it is very probable that the average represents the truth very closely.

Rapid Methods of Estimation.

The suspended matters in a water give to it a peculiar appearance called turbidity. It is, therefore, natural that this characteristic should be noted, and for some time analysts have been accustomed to express in some form the "turbidity" of the sample. In some cases this was given as the appearance of the untreated sample, and in others as the appearance of the supernatant liquid after subsidence had taken place for a certain period. In this paper we shall use the term "turbidity" as expressing the appearance of the sample after having been thoroughly shaken. The turbidity is, therefore, due to the presence of suspended matters, but while more or less elaborate means (including those described here) have been used in obtaining a measure of the turbidity, no one, so far as the writers are aware, has heretofore endeavored to establish a relation between the turbidity and the weight of the suspended matters present. Turbidity being an expression of appearance, which is an optical phenomenon, methods for measuring turbidity are naturally of an optical character, and while we may have made some apparent improvements in instruments or in their use, our attention has been practically devoted to the study of the constancy of observations and the interpretation of the turbidity readings in terms of the weight of the suspended matters.

Before taking up the several methods in detail, it will be well to note the leading factors which influence all of the processes, and to consider in a general way the principles upon which these observations are based.

The water which has been studied is that of the Ohio River, the observations dating back to 1896, when considerable work was done at Louisville, Kentucky, but the greater amount of the data was collected at Cincinnati during the fall and early winter of 1898.

The Ohio River water is fairly typical of the most turbid waters of this country, carrying at times great amounts of silt and clay in suspension. It is chiefly characterized by the sudden and great changes which take place in the amount and character of the suspended matters which it contains. Variations of ten fold in one day in the weight of suspended matters are not uncommon, and, judged from their hydraulic subsiding value, nearly as rapid changes take place in their character. Such a water, therefore, represents to a large degree the most extreme conditions under which the turbidity and the weight of suspended

matters may be compared on account of the changes in relation between the character and weight of suspended material. A grain of sand in a liter of water would not cause any turbidity, but if the grain of sand were replaced by an equal weight of millions of submicroscopical clay particles, the water would be decidedly turbid.

Agricultural chemists divide the material deposited from silt- and clay-bearing waters into three classes. These classes, which are noteworthy in this connection as representing the range in size of materials present, are as follows:

Sand.	Particles over 0.05 mm. diameter (hydraulic subsiding value).
Silt.	Particles between 0.05 and 0.005 mm. diameter.
Clay.	Particles less than 0.005 mm. diameter.

When it is borne in mind that each of the above classes is present in constantly varying amounts, it will be readily seen that it would appear extremely doubtful whether any expression or measurement of the appearance of a water could be expressed in terms of the weight of suspended matters present. On the other hand, it is these suspended matters that give the turbidity to the water through which they are distributed in very minute particles under any circumstances; and it was evident from the beginning of these studies that in a general way the greater the turbidity, the greater the weight of suspended matters.

As a part of any complete system of purification for waters carrying large amounts of suspended matters which will settle out readily, there will probably be more or less provision for plain subsidence. This action removes practically all of the sand, most of the silt, and some of the clay, the amounts increasing as the period of subsidence is increased. By this operation the range in character of suspended matters is reduced materially, and for the most part the turbidity of such a water is caused by clay particles only. In connection with the investigations of the Board of Trustees, "Commissioners of Water Works," of Cincinnati, Ohio, plain subsidence was a preliminary step in the systems of purification tested. We have, therefore, extended our study of the relation of turbidity to the weight of suspended matters to the subsided water also; and in the following pages the term "river water" is to be understood to refer to the water as pumped from the Ohio River at Cincinnati, and "subsided water" to refer to the same water after two or three days of plain subsidence,

during which from 60 to 80 per cent. of the suspended matters were removed.

Bearing the above points in mind, four different methods have been studied and are here discussed:

I. The first and simplest method consists in the comparison of the water with standards containing known amounts of suspended matters. These standards are prepared by dilution of water in which the weight of suspended matters has been determined.

II. The second method, which consisted in measuring directly the amount of light absorbed in its passage through the water, involved more or less elaborate apparatus, and has not as yet passed the experimental stage.

III. The third method is a very simple one which has been used for some time as a measure of turbidity — the determination of the vanishing depth of an object, commonly a bright wire.

IV. The fourth method was also the determination of a vanishing depth, but in this case light was transmitted up through the column of liquid and the vanishing object was the edge of the orifice admitting the light.

These methods are taken up and discussed in order.

I. Comparison with Standards.

Ohio River water was allowed to stand for several hours in a large bottle to permit of the sedimentation of the coarser particles. The supernatant liquid containing the finer clay particles was then siphoned off and the weight of the suspended matters carefully determined.

Standards containing varying amounts of suspended matters were prepared by dilution from this water and the samples compared with them in one-half gallon white glass bottles, both by reflected and transmitted light. Comparisons were also made in tubes using natural and artificial light and reflectors of white and of various colors. The light was transmitted up through the tube, and in some experiments side reflection was guarded against by special devices.

A series of experiments was also undertaken to find out the best method of preparing artificial clay standards, particularly for use in comparison with waters imperfectly clarified by filtration in order to estimate the very small quantity of finely divided clay which still remained. Kaolin and various clays were experimented with, and on account of the colored appearance of the water at times due to dis-

solved color and to finely divided oxides of iron, the addition of coloring agents such as methyl orange and caramel solutions was tried.

The result of this work led to the employment of the clay remaining in suspension in the Ohio River water as stated above, and to the use of methyl orange as a coloring agent. The best results were obtained by using Nessler cylinders of white glass, a white reflector, and diffused light. The comparison in bottles was much less accurate than in the tubes, and was soon abandoned.

Water which contains more than 25 parts per million of finely divided suspended clay, when viewed in a glass tube in a depth of 8 inches, is too turbid for the eye to distinguish differences with any accuracy. This method is therefore limited for practical purposes to waters containing less than 25 parts per million of suspended matters. Moreover, since silt and sand so seriously affect the weight of suspended matters without proportionally increasing the turbidity, this method is further limited to waters containing suspended material of a uniform and finely divided character, such as would occur in clay-bearing waters after a number of hours of subsidence, or in such a water imperfectly clarified by filtration.

The Ohio River water usually contains much more material in suspension than the above limit of 25 parts per million, and so this method is normally not applicable. During stages of very low water, however, the river water is freed by deposition in the river of practically all of its silt and sand, and contains for the most part only the finer clay particles. Under these conditions the weight of suspended matters may go below the above limit, and this method become available.

By the proper dilution with clear water of waters containing more than 25 parts per million of suspended matters, or by diminishing the depth of the column of liquid in which comparisons are made, this method would perhaps give approximate results of considerable value. Investigations along this line, however, were not carried far enough to warrant any very definite statements.

In the application of this method to turbid effluents, a series of 110 comparisons between readings with clay standards and the amount of suspended matters determined gravimetrically, showed that in about 25 per cent. of the results, the clay standards gave figures not quite 2 parts per million too high, and in 75 per cent. of the results not quite 5 parts per million too low. In other words, an average varia-

tion from 0–5 parts per million was apparent in comparing the two methods. Individual results showed very much wider differences, but the figures given probably represent approximately the truth.

It should be borne in mind, however, that the gravimetric results with such low amounts (all of them less than 25 parts per million) are as much open to suspicion as the results from comparison, and that the tendency of the gravimetric results to be higher than the others is very likely due to too low figures for the dissolved constituents, thus increasing the apparent amount of suspended matters.

The variation in the color of turbid waters containing small quantities of finely divided clay produced by dissolved vegetable matter and by suspended oxides of iron, is a rather serious difficulty in the use of this method. Coloring the standards so as to compare with the mean average color of the water is about the only remedy which can be applied. It has been found that increasing amounts of color were necessary as the amount of suspended matters in the standards increased. In our experience with Ohio River water, however, the periods covered by irregularities in color have been comparatively short, and no very great difficulty has been found in producing the proper adjustment of the standards.

In conclusion, it is believed that this method of comparison, carried out as described, will give on similar waters, as it has here, a satisfactory means of estimating the weight of finely divided suspended matters when present in amounts not exceeding 25 parts per million.

II. Photo–Comparator.

This instrument seems to have first been used extensively by James A. Seddon, C. E., in sedimentation studies at St. Louis, and is referred to in the *Journal of the Association of Engineering Societies* for 1889, Vol. VIII, page 477. It consists essentially of three parts, a glass cell to hold the water to be observed, two lights, and a photometer disk. These three parts are enclosed in a light-tight compartment or room, and so arranged that rays from one of the lights pass through the water in the glass cell. The photometer disk is placed between the water and the other light, and by finding the point where both sides of the disk are equally illuminated, the relative intensities of the rays from the two lights are measured. Comparisons with and without water in the glass compartment give the decrease in intensity of the light rays in passing through the water.

In our studies two Welsbach gas lights of about 50 candle power each were used. For holding the water wooden boxes with thin glass ends were employed, and the disk used was a standard Leeson disk. Several different cells were employed, varying from 0.25 to 3.0 inches in length of water section. Considerable difficulty was experienced in using this instrument, due in the main to the following factors:

1. It was found that variations in the relative strengths of the lights used were very large. Differences of 10 per cent. were obtained in a series of ten readings made within 15 to 20 minutes, while variations as high as 22 per cent. and 33 per cent. were noted on allowing an hour to intervene between two sets of readings, and on successive days, respectively. The latter figures are extreme, and probably 10 to 15 per cent. would represent the average fluctuation.

2. The absorption of the light rays by the water reduced the illumination of the disk. This necessitated the use of very thin strata of water when it was very turbid. It was evident that in order to maintain a sufficient illumination of the disk to determine clearly the end point, several different water cells of varying depths would be required, and possibly lights of different intensities. The intervention of the empty cell, and also of the cell filled with distilled water had very appreciable effects on the relative intensities of the lights. This amounted to from 8 to 24 per cent. for the effect of the cell alone, and to from 10 to 30 per cent. for the effect of the cell filled with distilled water.

3. As the amount of suspended matters increased in the samples examined, a new factor appeared. The light rays emerging from the water cell became more and more scattered and were so extremely divergent that they seriously affected the distinctness of the vanishing point of the star on the disk.

4. For different waters different distances between the sources of light might be advisable. With water containing relatively low amounts of suspended matters, the base line used in this instrument, 100 inches, was apparently quite satisfactory, but with more turbid waters it was evidently too long to maintain a sufficient illumination of the disk for satisfactory observation.

5. It appeared that subsidence in the cell during the reading of the strength of the light rays might cause a marked reduction in the amount of suspended matters in the sample, and the estimation would, therefore, be too low.

With the device as constructed, our preliminary experiments indicated that quite small differences in the amount of suspended matters could be detected. A series of samples in which the suspended matters ranged between 60 and 800 parts per million, and where the thickness of the stratum employed was one-half inch, showed that differences of less than 10 parts per million could not be readily distinguished. If, however, the thickness of the stratum was increased when estimating low amounts of suspended matters, very much better results could be obtained, as was shown by using cells from 1 to 3 inches in length.

It was evident that quite extended study would be required to establish clearly the best details for the device in order to put it into practical shape. This fact combined with the cumbersome character of the instrument and the development of information along other lines, which promised more immediate results, caused us to discontinue temporarily its further study. It should be pointed out, however, that the difficulties all appear capable of solution and that our limited study of the instrument should only be regarded as preliminary.

III. Wire Method.

This method is said to have been used in Europe for some time, and was first employed in this country, so far as our definite knowledge goes, about ten years ago, at the Lawrence Experiment Station[1] as a measure of the turbidity of sewage. It consists in the determination of the depth of liquid through which a small bright wire can be seen. The method has not been used enough to establish any standard procedure, so we have employed both a platinum and a copper wire of about .012 inch in diameter (No. 30 B. W. G.) and about 1 inch long. The wire was attached to the end of a measuring rod, and when used was simply immersed in the water, the depth at which the wire disappeared being read off on the rod. The readings were made in vessels of varying shape and capacity in diffused light, (*i. e.*, not in direct sun light).

The first question that was considered was the possibility of a direct and simple relation between the weight of suspended matters and the turbidity reading (which was recorded as the reciprocal of the vanishing depth in inches), when the suspended matters were all of

[1] Report Massachusetts State Board of Health, 1890, Vol. II.

the same general character. For this purpose several experiments were made, of which the following table is representative, the various samples having been obtained by successive dilutions.

Weight of suspended matters. (Parts per million.)	Turbidity.	Weight divided by turbidity.
33	0.17	195
62	0.30	198
126	0.49	252
248	0.86	275
342	1.02	335
453	1.14	344
528	1.43	370
634	1.73	368
792	2.00	396
1,057	2.67	391
1,585	3.13	507

These data show clearly that no direct relation existed between the weight and the turbidity, but in a general way they seemed to follow the same curve. This was sufficiently interesting and suggestive to warrant the collection of more data, and, accordingly, observations were made regularly upon the river water and upon the subsided water. The first question which arises in the study of the observations is this: Does the same turbidity reading always indicate the same amount of suspended matters, and if not, what is the range?

The following table was compiled from observations made on river water. All of the observations were arranged according to turbidity readings, and where more than two similar readings had been made, the corresponding weights of suspended matters (determined gravimetrically) were averaged, and the percentages which the maximum and minimum weights in each case were of the average, were determined.

These data show that a turbidity reading did not necessarily mean the same weight of suspended material, but that for the same readings differences of from + 42 to — 54 per cent. of the average might be found. On the average the range was from + 17 to — 21 per cent.

TABLE SHOWING THE RANGE IN WEIGHT OF SUSPENDED MATTERS IN OHIO RIVER WATER FOR THE SAME TURBIDITIES.

Turbidity.	Average weight of suspended matters. (Parts per million.)	Percentage which the maximum weight was of the average.	Percentage which the minimum weight was of the average.
0.20	49	130	71
0.21	64	123	61
0.22	45	120	82
0.28	75	101	96
0.40	122	123	77
0.45	116	107	94
0.47	195	101	99
0.50	143	142	46
0.57	211	105	82
0.67	223	121	80
0.80	278	113	70
0.89	267	117	82
1.00	334	117	82
2.00	766	120	79

In a similar manner the results on subsided water have been averaged, and show a range of from + 28 to — 32 per cent., the average range being + 10 to — 15 per cent.

TABLE SHOWING THE RANGE IN WEIGHT OF SUSPENDED MATTERS IN SUBSIDED WATER FOR THE SAME TURBIDITIES.

Turbidity.	Average weight of suspended matters. (Parts per million.)	Percentage which the maximum weight was of the average.	Percentage which the minimum weight was of the average.
0.11	16	100	100
0.12	14	128	71
0.19	20	115	80
0.28	35	114	86
0.29	50	100	100
0.33	53	107	85
0.36	85	107	91
0.50	89	107	84
1.00	172	116	68

From these tables certain facts are clearly brought out. The first one is that while at times the actual amount of suspended matters may differ considerably from that which would be indicated on the average by any turbidity reading, yet, practically speaking, the turbidity observations can be translated in terms of weight of suspended matters with an accuracy which, all things considered, is quite remarkable.

The second fact is that the same turbidity reading does not represent anything like the same amount of suspended material in a subsided water that it does before subsidence has taken place; in fact, the ratio is almost exactly twofold.

Finally, it is evident that in a general way increased turbidities mean increased material in suspension, but not in a uniform manner.

These topics will all be taken up again under the discussion of the diaphanometer, and there are only presented further in direct connection with the wire method some special comments on the difficulties in the application of the method.

The first and most important difficulty is the strength and character of the light. In this method light rays pass downward through the water, and a certain number of them are reflected upward again to the eye. A limiting point is attained when a sufficient number no longer reach the eye to define the outlines of the wire. The number of rays which pass to the eye is of course dependent on the number of rays entering the water, and their strength and direction. For this purpose (as the reflection from the surface of rays from a direct source of light would blind the eye) diffused, *i. e.*, not direct, sunlight seems most suitable. Its strength is, however, not controllable, and it is not available save for a small percentage of the time on clear days and not at all on cloudy ones or at night. These reasons alone made the method much less desirable than one in which the conditions were capable of better control.

Naturally, the suspended material must be well distributed through the water before observations are taken, but as a large surface is required in order to admit all of the light rays (limitations of area would have different percentage effects for different depths), rather large receptacles are necessary in which to make the observations. Under these conditions it is very difficult to insure thorough mixing of the samples, and not start up a wave motion which prevents the passage of light through the surface of the liquid. This difficulty could, however, be controlled by construction of a special compartment through which the water was kept flowing.

Finally, it is essential that a wire of the same size and character of surface should be used for all observations.

The only one of these points not capable of ready solution seemed to be the source of light, and on this account our attention was directed more and more to instruments and methods in which the source of light could be controlled within reasonable limits. The preliminary work on the photo-comparator has already been presented, and the work on the fourth method in which, like the photo-comparator, the light was artificial, will now be considered.

IV. Diaphanometer.

This instrument consists essentially of a tube with a transparent diaphragm at the lower end. Light is reflected up through this tube, and water is admitted until an image painted on the diaphragm just disappears. The reciprocal of the depth is taken as the turbidity reading, and corresponds in a general way with the turbidity reading by the wire method. This general device or method was used quite extensively by George Hornung, C. E., in studies made upon Ohio River water at Newport, Kentucky, during 1876 and 1877.[1]

Experiments were made by the writers during the course of several years of more or less regular use of this instrument with tubes of metal and glass, with various forms of diaphragm and with different kinds of light. These studies developed certain apparent principles upon which the present form of instrument is based.

1. The distinctness or sharpness with which the image loses its form is increased as the intensity of the light is increased, the most satisfactory vanishing points having been found with directly reflected sunlight.

2. It is essential that the intensity of the light be practically constant and uniform at all times.

3. The most satisfactory image, as determined by the distinctness of the vanishing depth, is a small transparent cross on a dark field.

4. With the metal tube the inside of the tube should be dull, not bright, but need not necessarily be painted.

In its present form, the device consists of a copper tube 1.375 inches in diameter, and 49.75 inches long. At the bottom of this tube is a glass diaphragm which is partially painted on its under side. The unpainted portion of the diaphragm forms a cross of two lines,

[1] See Report of Engineer and Superintendent of Newport Water Works for 1876. Method and apparatus described in a paper read before Cincinnati Society of Civil Engineers in March, 1896. Abstract of paper given in *Engineering News*, April 2, 1896.

each 1 millimeter wide, crossing in the center and extending to the edge of the disk.

The light used is from a Welsbach gas lamp of about 50 candle power. The rays of light from the lamp are condensed by a 4-inch double plano-convex condenser of about 12 diameters magnification. The light is reflected up through the tube by means of a plane mirror.

The lamp, condenser, and mirror are inclosed in a plain wooden box painted black on the inside and provided with suitable ventilating arrangements. The diaphanometer tube is inserted through an opening in this box, in which it fits closely and rests upon a shoulder with the diaphragm about 2 inches above the mirror.

The tube is easily removable, and for the purpose of observation is set into the box empty, and the water to be examined is poured in at the top until the depth is sufficient to cause the semblance of the cross to be entirely lost. With a little experience this end point is readily determined with most waters. A series of independent readings by different observers indicated that the error due to personal equation was not more than $\pm$ 2.5 per cent. The depth of the water is determined from the volume introduced by its relation to the capacity of the tube.

The first series of observations made with this instrument for the purposes set forth in the introduction to this paper (the device having been used more or less as a measure of turbidity since early in 1896) was on the same set of dilution samples as were recorded under the wire method. As mentioned there, these samples were made by dilution of a very turbid water in the endeavor to determine whether any constant and simple relation existed between turbidity readings and weight determinations. This series gave the following results:

Weight of suspended matters. (Parts per million.)	Turbidity.	Weight divided by turbidity.
33	0.07	465
62	0.13	484
126	0.21	583
248	0.38	657
342	0.46	745
453	0.55	820
528	0.62	855
634	0.70	900
792	0.82	974
1,057	1.18	898
1,585	1.73	919

As in the case of the wire method, these results clearly indicated that there was no direct and simple mathematical relation between the two observations. It therefore became a question to determine the constancy of the meaning of a turbidity reading, as in the case of the wire method. For this purpose observations were continued on river water and subsided water for several months, and then all of the weights determined for any turbidity reading were averaged, and the range of weights for the same reading determined. These results are given for river water and subsided water in the following tables:

TABLE SHOWING THE RANGE IN WEIGHT OF SUSPENDED MATTERS IN OHIO RIVER WATER FOR THE SAME TURBIDITIES.

Turbidity.	Average weight of suspended matters. (Parts per million.)	Percentage which the maximum weight was of the average.	Percentage which the minimum weight was of the average.
0.049	28	100	100
0.050	40	102	95
0.052	48	104	96
0.066	52	121	77
0.070	55	125	73
0.087	61	123	75
0.115	117	112	93
0.154	137	114	85
0.172	208	116	86
0.200	184	101	98
0.217	222	111	92
0.238	308	108	91
0.278	312	125	85
0.286	382	103	96
0.322	495	121	76
0.345	676	137	63
0.476	535	100	100

This shows an extreme range of from + 37 to — 37 per cent. with an average range of from + 13 to — 12 per cent.

TABLE SHOWING THE RANGE IN WEIGHT OF SUSPENDED MATTERS IN SUBSIDED WATER FOR THE SAME TURBIDITIES.

Turbidity.	Average weight of suspended matters. (Parts per million.)	Percentage which the maximum weight was of the average.	Percentage which the minimum weight was of the average.
0.050	24	116	83
0.052	25	116	80
0.055	27	100	100
0.058	26	134	80
0.063	27	103	96
0.064	25	120	84
0.067	26	115	88
0.069	32	112	84
0.070	30	103	90
0.071	31	106	93
0.077	36	108	89
0.083	43	111	90
0.105	52	111	90
0.137	75	109	89
0.172	99	107	92
0.238	133	120	90
0.250	125	113	81
0.263	152	109	93
0.278	156	112	97
0.385	220	102	97
0.417	256	100	100

The data on subsided water show an extreme range of from + 34 to — 20 per cent., with an average range of from + 10 to — 11 per cent.

As stated under the discussion of the wire method, these results are sufficiently close to be of practical value as an estimation of the weight of the suspended matters present. In fact, as will be presented later, the actual use of the method shows that in a large majority of the cases the variations are not as great as would be indicated by the

above figures. We, therefore, sought first to determine in how far the normal range of character of suspended matters represented the range which might take place under extreme conditions, and as to whether the mixture of coarse and fine particles affected the relation mathematically, or whether there was some other factor present. The following table shows the quotients obtained by dividing the weight of suspended matters by the turbidity readings in each of three sets of samples. The first series of samples contained coarse suspended material obtained by sedimentation of muddy Ohio River water. The second series was from the supernatant water after sedimentation and contained very fine material, and the third set was from the original water.

Weight of Suspended matters. (Parts per million.)	Weight of Suspended Matters Divided by Turbidity.		
	Coarse material.	Fine material.	Mixture.
50	740	615	690
100	750	630	740
150	840	735	780
200	920	760	820
250	975	825	825
300	1,050	930	935
350	1,120	945	980
400	1,200	960	1,040

It will be seen that the fine material gave considerably higher turbidity readings than the coarse, and that the mixture was approximately the mean of the two. That the mixture was so nearly the mean indicates that the fine material exerted a much stronger influence on the turbidity reading than did the coarse material, for in the original water these materials were mixed in the proportion of about 4 parts by weight of coarse to 1 of fine. This explains the constancy of the turbidities as translated in terms of the weight of suspended matters. The fine material is the controlling factor, and a considerable addition of coarse material exerts but little influence in the turbidity reading.

There has now been presented an outline of the preliminary studies along the above lines, and it remains simply to record the practical application of the conclusions to which they led.

For reasons which were incidental to the operation of the experimental purification plant at Cincinnati, practical use of some means of estimating quickly the weight of suspended matters in the water after subsidence was very desirable, but it was not essential to make such estimations on the original river water. The following data apply, therefore, to subsided water only. The reasons for using the "diaphanometer" and "comparison with clay standards" methods were their equally satisfactory, if not greater degree of constancy as compared with other methods, and their great simplicity, ease of manipulation, and the control of the variables.

During the last four months of 1898, regular turbidity readings by the diaphanometer were made on subsided water, and these were translated into equivalent weights. At first this was done by a curve obtained from average readings and weight determinations. Later, however, this curve was sufficiently strengthened to obtain its equation. No apparently rational formula could be obtained to agree with the facts, largely, it is believed, on account of the complex character of the optical laws which apply to the method. A straight line formula of the form Weight = Constant (Turbidity — Constant′) was found to fit the observations very well, and the most probable constants were found by the method of least squares to be 600 and 0.01. Accordingly from early in October, all turbidity readings were translated into equivalent weights by this formula:

$$\text{Weight in parts per million} = 600\ (\text{Turbidity} - 0.01).$$

The results obtained in this way seemed to agree very well with actual determinations of weight. Below 25 parts per million, however, it was found that the length of the column of water became so great that the image was greatly reduced in size by the refraction of the meniscus, and its distinctness was largely impaired by what was apparently the effect of the water alone. Reliance was, therefore, placed in regular work on the comparison with standards below 25 parts per million, and on turbidity readings by the diaphanometer above this point.

The following tables have been prepared to show the relation between the estimated weights and the actual gravimetric determina-

tions. The observations are grouped in several sets for convenience in study, according to the parts per million of suspended matters.

WEIGHT OF SUSPENDED MATTERS IN PARTS PER MILLION IN SUBSIDED WATER.

GROUP.	No. of observations.	DETERMINED GRAVIMETRICALLY.			ESTIMATED BY DIAPHANOMETER.		
		Maximum.	Minimum.	Average.	Maximum.*	Minimum.*	Average.
25– 50 parts.	33	49	26	34	49	32	37
51–100 parts.	43	98	53	69	96	43	72
101–200 parts.	38	178	106	130	180	98	137
201–300 parts.	14	292	214	240	266	215	230

*On the same water as the maximum and minimum gravimetric determinations.

The following table brings out more distinctly the actual variations between the estimated and determined weights.

NUMBER OF TIMES WHEN THE ESTIMATED WEIGHT OF SUSPENDED MATTERS DIFFERED FROM THE GRAVIMETRIC DETERMINATION BY VARIOUS AMOUNTS.

GROUP.	NUMBER OF TIMES WHEN THE VARIATION WAS THE FOLLOWING AMOUNTS IN PARTS PER MILLION.				Average variation in parts per million.
Parts per million.	0 — 5	6 — 10	11 — 15	16 — 25	
Between 25 and 50 parts . .	21	10	2	0	3
Between 50 and 100 parts . .	20	16	7	1	1
Between 100 and 200 parts* .	18	14	4	2	9
Between 200 and 300 parts† .	2	4	4	3	14
Totals	61	44	17	6	..

* Four pairs of observations which are not included in the above, differed by 38, 39, 43 and 52 parts, respectively, the estimated weight being below the gravimetric weight by that amount. These were unquestionably due to particles of very heavy material not normally present in the water.

† One pair of observations differed by 27 parts, and is included in the average.

CONCLUSIONS.

The result of the study of the several methods may be summarized as follows:

1. The study of these methods has only been in connection with their application to the Ohio River water at Cincinnati before and

after sedimentation. This water, however, may be considered fairly typical of the muddy waters of this portion of the country, and the conclusions which are drawn are, therefore, probably true for this general class of waters.

2. By the method of comparison with standard clay solutions reasonably close estimations may be made of the weight of very finely divided suspended matters when they are present in amounts of less than 25 parts per million.

3. With regard to the photo-comparator, the studies were not advanced far enough to draw very definite conclusions, but after the solution of the essential details of the instrument it seems that this method might be made of value.

4. The wire method as now employed, is seriously handicapped by the question of the variation of light. In the absence of other methods, estimations could be made in this manner which would be of considerable value; and it seems possible that by certain modifications, such as the use of a water glass and artificial light, the conditions might be made equally as satisfactory as with the diaphanometer.

5. With waters containing more than 25 parts per million of suspended matters, the diaphanometer seems to give readings which can be translated in terms of weight of suspended matters with normally but a comparatively small error.

6. It must be borne in mind that the estimation of the weight of suspended matters by any of the above methods, is based upon the relation which the turbidity of the water bears to the weight of suspended matters present. If these matters are fairly uniform in character and the particles do not vary widely in size, then the above methods are accurate within reasonable limits, but as the suspended material becomes more varied in character, the particles differing widely as to size and specific gravity, then the greater becomes the error by any of the above methods, and the less reliance can be placed upon them.

7. Finally, the great convenience and rapidity with which fairly reliable results may be obtained by any of the four methods described, after careful standardization against the gravimetric method, are features which strongly commend them to persons requiring in practical work the class of information which they furnish.

LABORATORY OF COMMISSIONERS OF WATER WORKS,
Cincinnati, January 31, 1899.

ON THE DETERMINATION OF ADDED WATER IN MILK.

By A. G. WOODMAN.

In order to estimate the amount of water which has been added to a sample of milk it is generally necessary to make separate determinations of the specific gravity, the total solids, and the fat. The accurate determination of at least two of these factors is a matter of considerable time, and although it is possible to shorten the time to a certain extent by the use of such formulæ as those of Fleischmann, or of Hehner and Richmond, there can be no doubt that a rapid, and at the same time accurate method for determining the extent to which milk has been watered would find extensive application.

The most successful of the various methods by which it has been proposed to effect the direct determination of added water are based in general on the fact that under certain conditions the serum, or liquid portion of sour milk, possesses a fairly constant composition, much more so than the milk itself. The methods by which the milk serum is obtained depend for the most part upon the coagulation of the milk by dilute acid. Vieth[1] recommends letting the milk sour spontaneously by standing at the room temperature for two or three days, and then separating the serum from the coagulum at 65° C. Other investigators prefer to coagulate the milk directly by the addition of an acid. Dietsch[2] and Radulescu[3] use dilute acetic acid and warm the milk to a fairly low temperature. Reich[4] recommends the use of a small quantity of glacial acetic acid and final heating of the milk to 100° C. Sambuc[5] heats the milk to 40°–50° C. with 2 cc. of an alcoholic solution of tartaric acid of a specific gravity of 1.030–1.032, approximately the same as that of the milk serum itself. The whole question has been investigated quite thoroughly by Radulescu,

[1] Forschungen auf dem Gebiete der Viehhaltung und ihrer Erzeugnisse, 1884 (15), 334.
[2] Chem. Ztg., 1884, 323.
[3] Mitt. aus dem pharm. Ins. u. Labor. für ang. Chem. der Univ. Erlangen, 1890, III, 93.
[4] Milch-Ztg., 1892, 274.
[5] Jour. de Pharm. et de Chim., 1884, 95.

who has made a study of the conditions necessary in regard to the strength of acetic acid employed, the temperature to which the mixture should be heated, and the time required in order to obtain satisfactory results. The method recommended by Radulescu is as follows: To 100 cc. of the milk is added 2 cc. of 20 per cent. acetic acid, and the mixture is heated in a water bath at 85° C. for 5–10 minutes, as a result of which the casein separates in the form of a compact cake, and is easily filtered off. After being thoroughly mixed the filtrate is cooled to 15° C., and its specific gravity taken. The acid used is variously stated in different portions of Radulescu's paper to be 20 per cent. acetic acid, 25 per cent. acetic acid, and acetic acid having a specific gravity of 1.0294, which is about 22 per cent. strength. In the determinations which have been carried out, using practically the same method as that proposed by Radulescu, it has been found that for the richer samples of milk the 20 per cent. acid is too dilute, failing to entirely precipitate the casein, but that the acid of 25 per cent. strength is sufficient in all cases.

After a number of experiments, following at first as nearly as possible the procedure recommended by Radulescu, subsequently making such modifications in the method as were found advisable in order to secure more nearly uniform results, the following procedure has been adopted in the present investigation: 100 cc. of the milk, which should be at a temperature of about 20° C., is thoroughly mixed with 2 cc. of a 25 per cent. solution of acetic acid, specific gravity 1.0350, in a small beaker. The beakers, kept covered with watch glasses, are heated for 20 minutes in a water bath maintained at a temperature of 70° C., the temperature of the milk samples being brought gradually by this means to about 65° C. The beakers are then removed from the water bath and placed immediately in ice water, where they are allowed to remain for 10 or 15 minutes, after which the samples are filtered through small, dry, plaited filters, the first portion of the filtrate, which generally comes through cloudy, being returned to the filter. After the filtrate has been thoroughly mixed it is cooled to 15° C., and its specific gravity taken by means of a Westphal balance. It occasionally happens, more especially with normal milk, or milk to which only a slight amount of water has been added, that the milk serum which is thus obtained has a slight cloudiness or opalescence, but it has not been observed to cause any appreciable difference in the specific gravity. For assistance in studying the conditions upon which the above

procedure is based, credit is due to Mr. J. W. Brown and Miss J. H. Bartlett.

In the following table (Table I) will be found the results obtained on samples of pure milk obtained from various sources, and on mixtures of these milks containing varying percentages of water, by the method that has been outlined above. All determinations of specific gravity have been made at 15° C., using a delicate Westphal balance which gave the specific gravity of pure water at 15° as 0.0000.

TABLE I.

	Specific Gravity of						
	Milk.	Serum.					
No.		Normal.	10% water.	20% water.	30% water.	40% water.	50% water.
1.	1.0337	1.0297	1.0263	1.0237	1.0206	1.0180	1.0153
2.	1.0334	1.0294	1.0260	1.0232	1.0203	1.0174	1.0151
3.	1.0340	1.0295	1.0264	1.0232	1.0206	1.0175	1.0151
4.	1.0324	1.0293	1.0259	1.0233	1.0202	1.0178	1.0148
5.	1.0336	1.0296	1.0262	1.0235	1.0205	1.0177	1.0153
6.	1.0328	1.0293	1.0258	1.0233	1.0202	1.0174	1.0148
7.	1.0334	1.0292	1.0260	1.0233	1.0202	1.0175	1.0149
8.	1.0325	1.0294	1.0260	1.0234	1.0201	1.0175	1.0152
9.	1.0339	1.0296	1.0262	1.0236	1.0206	1.0178	1.0153
10.	1.0335	1.0296	1.0261	1.0235	1.0204	1.0174	1.0148
11.	1.0329	1.0292	1.0259	1.0234	1.0203	1.0173	1.0148
Av.	1.0335	1.0294	1.0261	1.0234	1.0204	1.0175	1.0150

The specific gravity of the serum from milk at a given dilution is shown by the table to be a fairly constant quantity, the average decrease for each 10 per cent. of water being .0031.

The specific gravities given in Table I were obtained on samples in which the percentage of water *in the mixture* varied by ten. As might naturally be expected, if the results are calculated on the basis of the percentage of *added* water, the differences in specific gravity are not so great. In Table II are given the results obtained on samples of pure milk to which varying percentages of water have been added.

TABLE II.

Samples varying by 10 per cent. *added* water.

	Specific Gravity of						
	Milk.	Serum.					
No.		Normal.	10% water.	20% water.	30% water.	40% water.	50% water.
1.	1.0336	1.0294	1.0259	1.0239	1.0219	1.0199	1.0189
2.	1.0333	1.0295	1.0260	1.0240	1.0220	1.0200	1.0190
3.	1.0334	1.0294	1.0259	1.0239	1.0220	1.0200	1.0190
4.	1.0330	1.0295	1.0260	1.0239	1.0221	1.0201	1.0190
5.	1.0324	1.0294	1.0259	1.0239	1.0220	1.0199	1.0190
6.	1.0328	1.0294	1.0260	1.0239	1.0220	1.0200	1.0190
7.	1.0340	1.0294	1.0260	1.0239	1.0220	1.0200	1.0190
8.	1.0337	1.0296	1.0261	1.0240	1.0221	1.0201	1.0190
9.	1.0330	1.0294	1.0259	1.0239	1.0221	1.0200	1.0190
10.	1.0335	1.0295	1.0260	1.0239	1.0220	1.0199	1.0189
Av.	1.03327	1.02945	1.02597	1.02392	1.02202	1.01999	1.01898

These results confirm the conclusion reached by Radulescu that the specific gravity of the serum from normal milk is never below 1.027, and in no case of those examined was it found to be below 1.0290. The decrease in specific gravity caused by the addition of 10 per cent. of water varied from 0.0035 to 0.0010. The statement is made by Radulescu (*loc. cit.*) that the addition of each 10 per cent. of water to normal milk lowers the specific gravity of the serum by 0.0005 to 0.0010, and this value is also found in text books which treat of the subject, for example, in König.[1] This would seem to be due to some clerical error, for from the preceding table it will be seen that the decrease actually obtained is considerably higher, and as a matter of fact the differences shown in Radulescu's tabulation of results vary from 0.0029 to 0.0012. Radulescu further recommends to determine the total amount of solids, and also the fat in the milk serum; but this does not seem to me to be advisable, because if it is done, the method offers no special advantages as regards economy of time and ease of execution over those ordinarily used.

[1] Die Untersuchung landwirtschaftlich und gewerblich wichtiger Stoffe. Ed. 1898, 361.

The method as originally proposed by Radulescu has been criticized by Reich[2] on the ground that only a partial clarification of the milk is effected, the precipitation and removal of the albumen not being complete at the temperature to which the milk is heated. The following modification of the method has been proposed by Reich: 100 cc. of the milk is thoroughly shaken in a 200 cc. flask with 0.4 cc. of glacial acetic acid, the mixture heated for 5–6 minutes at 60–65° C., cooled and the liquid portion poured off into 50 cc. Erlenmeyer flasks. These are hung for 5–6 minutes in a bath of boiling water, then rapidly cooled in ice water. The casein and albumen are removed by filtering through a small dry Swedish filter and the specific gravity of the filtrate taken at 15° C. The specific gravity of the serum from five samples of milk diluted with varying percentages of water has been determined by Reich's method, and also of the same samples by the modification of Radulescu's method previously described. These results are given in the following table.

TABLE III.

	Specific Gravity of						
	Milk.	Serum.					
No.		Normal.	10% water.	20% water.	30% water.	40% water.	50% water.
	(*a*) According to the modified Radulescu method.						
1.	1.0337	1.0294	1.0259	1.0239	1.0220	1.0199	1.0190
2.	1.0319	1.0294	1.0260	1.0240	1.0220	1.0199	1.0190
3.	1.0338	1.0295	1.0260	1.0239	1.0220	1.0200	1.0189
4.	1.0340	1.0294	1.0259	1.0239	1.0219	1.0200	1.0189
5.	1.0328	1.0294	1.0260	1.0240	1.0220	1.0200	1.0190
	(*b*) According to Reich's method.						
1.	1.0337	1.0293	1.0266	1.0240	1.0224	1.0205	1.0196
2.	1.0319	1.0289	1.0257	1.0234	1.0219	1.0200	1.0182
3.	1.0338	1.0292	1.0264	1.0245	1.0226	1.0207	1.0199
4.	1.0340	1.0296	1.0264	1.0243	1.0225	1.0205	1.0198
5.	1.0328	1.0295	1.0270	1.0247	1.0217	1.0210	1.0199

[2] Milch-Ztg., 1892, 274.

The claim of Reich that his method yields concordant results which are uniformly lower than those obtained by Radulescu's method is not borne out by the results shown in Table III. It has been found by experience that the method offers no advantages over that of Radulescu, being more tedious to carry out, and giving results which differ more widely.

As an illustration of the degree of accuracy with which the amount of added water in milk can be estimated from the specific gravity of the milk serum, may be given the following results obtained on two samples purchased at a city grocery, and supposed to be pure milk.

	1.	2.
Specific gravity of milk	1.0282	1.0263
Specific gravity of serum . . . . . : . .	1.0257	1.0234

The specific gravity of the serum indicated in one case 10 per cent., and in the other 20 per cent. of added water. The amount of added water calculated from careful determinations of the total solids and of the fat was very close to this, being 9.8 per cent. for the first sample, and 19.6 per cent. for the second.

The method as described has been found easy to carry out, and capable of yielding satisfactory results. As a quick method for the estimation of the extent to which milk has been watered, it should prove of considerable value, this being undoubtedly the most common method for the adulteration of milk.

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ASSAYING TELLURIDE ORES FOR GOLD.

By RICHARD W. LODGE.

Received April 15, 1899.

At one time the scorification method was considered the only correct one to use on ores of this character. Recently numerous papers have been published in regard to the correct method of assaying such ores, and many different charges and methods have been suggested. No doubt all of these have their advocates, and in their hands satisfactory results may be obtained; but my own experience is that a rich gold ore containing tellurium can be assayed by either the scorification or crucible method with equally satisfactory results, always provided that the ore has been ground to a sufficient degree of fineness. For the majority of rich ores this is not less than what will pass through a 140-mesh sieve, or finer if possible. In other words, the richer the ore, the finer the sieve should be through which it should be passed.

The following experiments, made by Mr. A. L. Davis, a graduate of 1898 in our course of Mining Engineering, may be of interest to assayers, and may illustrate some of the points it is desired to bring out. These experiments were made in 1897, and carried out in a most thorough and careful manner. The ore selected for the work came from Boulder County, Colorado, and gave a strong test for tellurium. The percentage was not determined. The gangue was chiefly quartz with tellurides and pyrite scattered through it. It was pulverized and passed through a 100-mesh sieve. Assays made by myself showed $68\frac{6}{10}$ ounces gold by the scorification method, and $68\frac{3}{10}$ ounces gold by the crucible method of assay, no correction being made for gold left in slag and cupel. The ore had a reducing power of $1\frac{2}{10}$.

In the experiments carried out by Mr. Davis four different crucible charges were tried, and three different scorification charges. In each experiment the slags and cupels were saved, ground separately and assayed, in order to trace the loss of gold if there was any. The

results are shown in the accompanying tables. From the tables it will be seen that, in the scorification process, some gold is always lost in the slag, and that it is larger than the loss sustained in cupellation, which of course is the rule in gold assays. In the crucible process there is also a loss of gold in the slag, but the percentage loss seems to be less than that sustained in cupellation.

As the ore carried very little silver, enough pure silver was added to all the lead buttons at the time of cupellation to part the resultant bead. It may be of interest to state that tests upon the bone ash from which the cupels were made by us showed that

3.5% would remain on a 60-mesh sieve.
15.9% would pass 60 and remain on 80.
27.8% would pass 80 and remain on 100.
52.8% would pass through 100 mesh sieve.

SCORIFICATION METHOD.

Charges.	No. of experiments.	Wt. of lead button.	Wt. after rescorifying. Wt. after 3d scorification.	Wt. of gold after parting (grammes.)	Gold found in slag.	Gold found in cupel.	Total gold.	Ounces per ton.	Per cent. of total gold found in slag.	Per cent. of total gold found in cupel.
I. Ore $\frac{1}{10}$ A. T.	1*a*	30	20 —	.00622	.00005	.00004	.00631	$63\frac{1}{10}$	.79%	.63%
I. Gran. lead, 60 grams	2*b*	30	Cupelled.	.00648	—	—	—	$64\frac{8}{10}$	—	—
I. ($\frac{1}{2}$ mixed with ore, $\frac{1}{2}$ placed on top)	3*c*	31	Cupelled.	.00690	Trace.	Trace.	.00690	69	.00	00
Borax glass, a pinch on top of all.										
II. Ore $\frac{1}{10}$ A. T.	1*e*	34	22 —	.00686	.00004	None.	.00690	69	.58%	None.
II. Gran. lead, 45 grams. ($\frac{1}{2}$ mixed with ore.)	2*f*	25	Cupelled.	.00648	.00005	.00005	.00658	$65\frac{8}{10}$	.76%	.76%
II. PbO cover 10 grams	3*g*	25	Cupelled.	.00650	.00010	.00006	.00666	$66\frac{6}{10}$	1.50%	.90%
Borax glass, 0.3 grams on top of all.										
III. Ore $\frac{1}{10}$ A. T.	1*h*	48	37 20	.00684	.00005	None.	.00689	$68\frac{9}{10}$	.71%	None.
III. Gran. lead, 60 grams	2*j*	49	25 —	.00647	Trace.	.00005	.00652	$65\frac{2}{10}$	.00	.77%
III. PbO 1 A. T.										

Assays *a*, *e*, and *h* were all made at the same time and under conditions as nearly alike as possible.
Assays *b*, *f*, and *j* were all made at the same time and under like conditions.

CRUCIBLE METHOD.

	Charges.	No. of experiments.	Weight of lead.	Wt. after scorifying once.	Wt. after scorifying twice.	Wt. of gold obtained in grams.	Wt. of gold found in slag.	Wt. of gold found in cupel.	Total gold accounted for.	Ounces per ton.	Per cent. of total gold found in slag.	Per cent. of total gold found in cupel.
I. Mix.	Ore ½ A. T. Soda 60 grams PbO 120 grams Argols 1 gram	1	30	—	—	.03391	.00007	.00008	.03406	$68\frac{12}{100}$	.21%	.23%
		2	27	—	—	.03417	.00019	Lost.	.03436	$68\frac{72}{100}$	.56%	—
	Borax glass cover.											
II. Mix.	Ore ½ A. T. Soda 20 grams PbO 80 grams Gran. Pb, 50 grams Argols 1 gram	1	80	47	21	.03463	None.	None.	.03463	$69\frac{28}{100}$	None.	None.
		2	75	51	25	.03387	.00008	.00012	.03407	$68\frac{14}{100}$	.24%	.35%
	Cover of salt.											
III. Mix.	Ore ½ A. T. Soda 40 grams PbO 60 grams Borax glass 15 grams Argols 1 gram	1	29	—	—	.03393	Trace.	.00008	.03401	68.02	—	.24%
		2	25	—	—	.03414	.00005	.00014	.03433	$68\frac{66}{100}$	.15%	.41%
		3	25	—	—	.03401	Trace.	.00016	.03417	$68\frac{34}{100}$	—	.46%
	Cover of salt.											
IV. Mix.	Ore 1 A. T. Soda 60 grams Borax glass 15 grams PbO 60 grams Niter 1 gram	1	25	—	—	.06698	.00009	.00005	.06712	$67\frac{12}{100}$	.13%	.07%
		2	28	—	—	.06820	.00011	.00015	.06846	$68\frac{46}{100}$	.16%	.22%
	Cover of salt											

From the foregoing tables it is very evident that the ore, setting aside the loss through volatilization, assays between 68 and 69 ounces per ton, and any results below this are due to the ore weighed out not being a correct or even sample of the whole. Of the eight scorification assays three are practically correct, and are within the limits of error of assay with no correction made for the gold found in the slag and cupel. The remaining five are all too low, even with the corrections made, and there seems no way for accounting for these low results other than that the portion of ore taken was an incorrect sample of the whole.

The crucible results are much more even, and the percentage of loss sustained both in the slag and in cupellation lower than in the scorification method. As the amount of ore taken is five times larger in seven cases, and ten times larger in two cases than in the scorification method, this may account for the more uniform results and the smaller percentage of loss sustained.

As for the charges used, no comparison is drawn. Our only regret is that the sample of ore was so small that we were unable to carry out further experiments which the above results suggest. No doubt if the ore had been crushed to pass through a 160 or 180-mesh sieve, more uniform results would have been obtained in the scorification method. It was only a short time ago when a 60-mesh sieve was considered sufficiently fine to pass any ore through previous to assaying. This was then set aside for an 80-mesh, and now a 100-mesh is generally used in most assay offices. I believe it only a question of time when every sample will have to pass a 140-mesh. What assayers need is a machine easily cleaned, which will grind ores through such a sieve quickly, and at the same time not contaminate the sample with the iron or material of which the machine is made. The foregoing experiments also bring up the questions of how close assay results should check, and what the percentage of loss is in assay work.

As to the first question, some ores will check easily, even if the ore is ground no finer than through a 60-mesh sieve, but these are the exceptions. With other ores, even when ground so fine that they will pass through bolting cloth finer than 200 meshes to the inch, it seems impossible to obtain anything like uniform results.

As to the percentage of loss sustained in work, whether by the scorification or the crucible method, many experiments carried out upon the foregoing lines, both upon silver and gold ores, indicate to me that nothing definite can be laid down in regard to it. Every ore, every slag, every scorification, and every cupel, let alone the temperature at which the assay is carried on, has some effect upon the loss, and these make too many unknown quantities to arrive at any definite conclusion.

NOTES ON AN UNUSUAL ORIENTATION OF PHENOCRYSTS IN A DIKE.

BY MYRON L. FULLER.

Received April 21, 1899.

PORPHYRITIC crystals, or phenocrysts, as they have been named by Iddings, are the more or less perfect crystals of igneous rocks occurring in a matrix, or ground mass, of smaller and more irregular individuals, or in a glass. The usual view is that they represent the crystallization of an earlier and deeper (intratelluric) stage of the magma before its final intrusion or ejection, as the case may be. In those instances where their major axes have an orientation parallel to the walls (in intrusions) or to the surface of the flow (in extrusive masses) the evidence is clear that the arrangement is due to the flowage of the magma, and indicates conclusively a prior existence of the phenocrysts. The necessity of considering them in all cases as representing an intratelluric stage has, however, been doubted by several petrographers of note,[1] and recently Pirsson[2] has strongly urged *development in place* as the probable explanation for practically all phenocrysts of intrusive rocks.

There are four general ways in which phenocrysts may be arranged in a dike. In the first, the individuals may be distributed, either regularly or irregularly, throughout the mass and possess no definite orientation of their axes; in the second, the larger axes have an orientation parallel to the walls of the dike; in the third, the longer axes lie in a horizontal plane, while in the fourth there is a parallel arrangement other than horizontal, and having no relation to the walls.

It is to the third or fourth group that the occurrence to be described belongs. The dike in question was noted on the shore of Rand's Pond in the town of Goshen, Sullivan County, New Hampshire, and is exposed for a distance of some 175 feet. It varies in width from 1 to 3 feet. The wall rock is a rather coarse, dark colored, micaceous gneiss

[1] Zirkel, Lehrbuch der Petrographie, Vol. I, p. 731, et seq. 1893. Cross, 14th Ann. Rept. U. S. Geol. Surv., p. 231.

[2] Am. J. Sci. IV, Vol. 7, 271–280.

with a well developed lamination. On the map[1] it is given as the "fine grained" Bethlehem gneiss, but to the eye is indistinguishable from much of the Winnipiseogee gneiss, which, however, is not indicated as appearing for nearly a mile to the westward.

The dike rock is a porphyritic granite similar in its general character to that of a large area of porphyritic granite (designated as the Main Area[2]), the western boundary of which lies only about two miles to the eastward. The interest in the dike arises from the unusual orientation of the orthoclase phenocrysts. These are from 1 to 2 inches in length, and possess a common orientation which, instead of being parallel to the walls, agrees exactly with the lamination of the

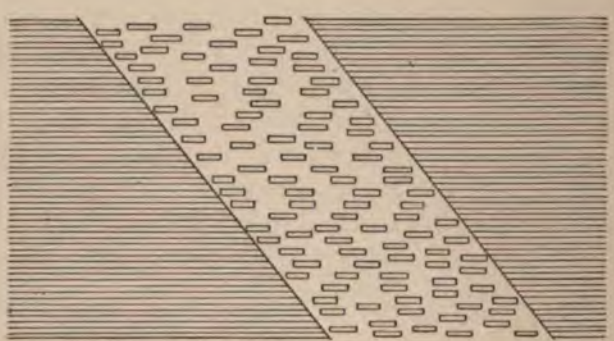

FIG. 1.—SECTION PARALLEL WITH STRIKE, SHOWING RELATION OF PHENOCRYSTS TO LAMINATION OF THE GNEISS. RAND'S POND, GOSHEN, N. H.

neighboring gneiss, which here dips to the eastward at an angle of some 35°. This relation is clearly brought out in the figure.

In seeking a cause of the arrangement it is necessary to make certain assumptions as to the conditions obtaining at the time of solidification. We can either consider that the lamination of the gneiss and the orientation of the phenocrysts were both horizontal at the time of solidification of the dike, or we may regard the present attitudes as original.

Leaving out of account the horizontal lamination which the gneiss would have possessed under the former of these suppositions, and which would point towards a sedimentary origin, there remains the

[1] Atlas accompanying the Report on the Geology of New Hampshire. C. H. Hitchcock, 1878.

[2] Daly, Jour. Geol., 5, 702.

horizontal arrangement of the phenocrysts to be accounted for. This arrangement would exclude the agencies of pressure and flowage as determining causes, and the action of gravity seems to be the only agent available.

Tabular particles, especially if of considerable size, tend, when settling in a solution of nearly equal specific gravity, to sink with their broader planes in a roughly horizontal position. Thus phenocrysts, if heavier than the inclosing magma, might be conceived as arranging themselves in parallel positions if the dike was vertical. In the case in question the dike would have cut the horizontal gneiss at a large angle, and if any settling of the phenocrysts had occurred, there would inevitably have been some tendency along the foot wall (because of the arrest of the phenocrysts) to an arrangement parallel to its plane.

It is, however, extremely doubtful if phenocrysts of orthoclase would settle at all in a granitic magma of the type occurring in the dike. It is true that a certain increase in density takes place when minerals crystallize from a magma, but Mallet's observations on the solidification of plate glass, taken as a representative of acid rocks, show that the increase is very slight (about 1.6 per cent.). This would be offset, in all probability, by the greater basicity of the remaining magma. The fact that while the specific gravity of the orthoclase is not over 2.59, that of the surrounding granite is approximately 2.73, gives weight to this view.[1]

The viscosity of the magma would also tend to so neutralize the effect of slight differences of density that a sinking by gravitation, if it took place at all, would be comparatively unimportant in character, especially while the magma retained its upward motion.

The absence of a feasible explanation of the arrangements of the phenocrysts under the conditions assumed is a strong argument against the existence of such conditions. We are led, therefore, to the consideration of the second supposition, *i. e.*, that the attitude of the lamination of the gneiss and the orientation of the phenocrysts have remained unchanged since the consolidation of the dike. Flowage is again ruled out as a possible cause of the orientation. Gravitation is likewise eliminated because of the inclination of the laminæ of the gneiss to which the phenocrysts are parallel.

[1] The specific gravity determinations were made upon the porphyritic granite from the Fitchburg, Mass., district, no specimens from the dike itself being available. The two are, however, identical in character.

Pressure seems to be the only agency capable of producing the features observed. If, while the magma was still plastic, it was subjected to pressure, the mobility of its particles would be sufficient to readily admit of an orientation of the phenocrysts in planes perpendicular to the direction of the pressure, in a manner analogous to that of mica scales in the experiments of Sorby on slaty cleavage. Likewise, if deeply buried, the heat and pressure acting during a period of compression might easily be sufficient to cause the rocks to behave as if plastic, and the same orientation would result. The action of

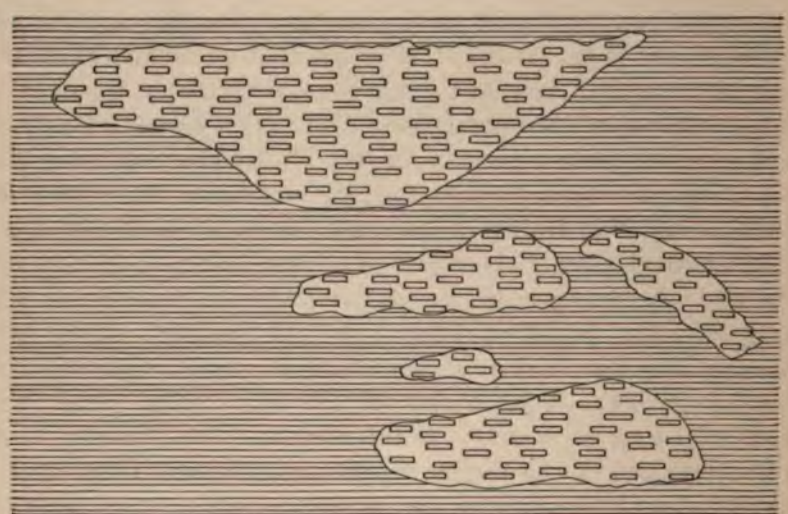

FIG. 2.—PLAN, SHOWING RELATION OF THE PHENOCRYSTS OF INCLUSIONS TO THE LAMINATION OF THE INCLOSING GNEISSIC GRANITE. SUNAPEE, N. H.

pressure on the plastic rock is probably the true explanation of the unusual orientation described.

What is probably an analogous case is found in the fragments of banded porphyritic granite included in the so-called Winnipiseogee gneiss on a hill in the southern part of the town of Sunapee. Here, whatever the relation of the included fragments to the lamination of the gneiss, there is a close agreement, in all cases noted, between the orientation of the phenocrysts and the lamination.

Figure 2 shows the arrangement of such a group of inclusions.

That such a uniform parallelism of orientation should be due to an accidental arrangement is highly improbable, and connection with the

parent rock is impossible. The only feasible view seems to be that the orientation here, as in the case of the dike, was due to the action of pressure upon the more or less plastic inclusions. This view finds support from the nature of some of the contacts. The inclusions of the granite gradually become less massive as the gneiss is approached, and show a fraying out, until finally the only indication of the former extension of the granite is the occurrence of badly corroded phenocrysts in the adjoining gneiss. A degree of heat capable of producing such results is amply sufficient to account for the assumed plasticity of the inclusions.

The relation of the porphyritic granite to the gneiss here noted is just the reverse of that assumed by Daly[1] from apparently unimpeachable evidence. This apparent inconsistency may be due to the fact that the area mapped as Winnipiseogee gneiss may, in reality, include several rocks of similar appearance but of diverse origin, some of which are older and some younger than the porphyritic granite. The diverse natures of the rocks of the Winnipiseogee series was noted by Daly.[2]

The correspondence between the lamination of the so-called gneisses and the arrangement of the phenocrysts, which is so marked in both instances described, might appear to indicate a similar origin for both. This, however, is probably not the case. Daly has shown[3] that the lamination of the porphyritic granite is, in all probability, a flow structure. The so-called Winnipiseogee gneiss, at least in the locality described in the town of Sunapee, appears from its field relations to be likewise an igneous intrusion, and it is not unlikely that the lamination is a flow structure. The axes of disturbance in this region have a general north-south direction, or, in other words, are parallel to the main intrusive masses. The pressure, which would normally be at right angles to the flow structure, would therefore cooperate with it. In the small dikes, on the other hand, which cut diagonally across the lamination of the inclosing rocks, the direction of pressure would be inclined to the lines of flow, and would act more or less in opposition to it. At Rand's Pond pressure was clearly the predominating factor in determining the orientation.

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[1] Jour. Geol., 5, 708–713, 720–722.
[2] Jour. Geol., 5, 721.
[3] Jour. Geol., 5, 780–789.

ON A METHOD OF MEASURING THE FREQUENCY OF ALTERNATING CURRENTS.

By HARRISON W. SMITH.

Received April 24, 1899.

THE following is a brief description of a method recently employed at the Institute for measuring variations in the frequency of currents of about 120 alternations per second. With the exception of Figure 2 the diagrams are not drawn to scale, while Figure 1 is devoted largely to the arrangement of connections used in the electrical driving of the tuning fork.

A weighted fork (Figure 1) is mounted horizontally and is provided with a metallic contact-maker *D*, consisting of a sharp-pointed stile

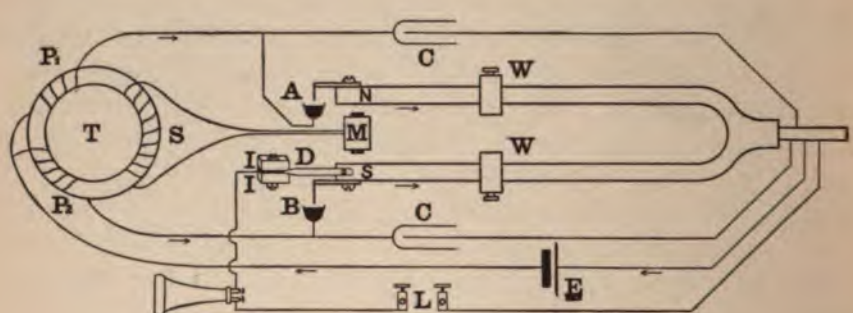

FIG. 1.

(attached to the prong *S*) which vibrates over a smooth surface formed by two blocks of ivory *I I*, separated by a sheet of platinum about 0.02 inch thick. The ivory blocks are firmly clamped together and the surface is then highly polished, so that the stile while vibrating and pressing lightly against it shall encounter as little friction as possible. This part of the contact-maker is so mounted as to be capable of vertical adjustment in order that the stile may make contact with the platinum at the middle of the stroke of the prong. The contact-maker is then connected in series through the fork with a telephone (Figure 1) and attached at *L* to the source of alternating current, the

frequency of which is to be measured. When, now, the fork is set in vibration, the stile makes contact at the middle of each stroke of the prong, and if the periodicity of the alternating current is the same as that of the fork, the contacts will occur at the same point on each successive current wave: there will then be a steady sound in the telephone or no sound, depending on the difference of phase between the current and the fork. If, however, the periodicity of the current and fork differ slightly, there will be fluctuations of sound causing marked "beats;" the frequency of the beats depending on the amount by which the periodicity of the current and fork differ. The weights *W W* are then adjusted by repeated trials until there are no beats, and as the fork has been previously rated, we know directly the periodicity of the current.

Figure 2 indicates the manner in which the beats occur. *AB* and *AC* on the same scale represent, respectively, ten complete sinusoidal

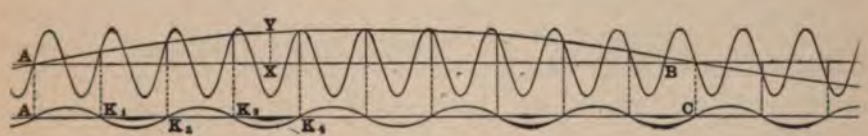

FIG. 2.

alternations of current and ten single vibrations of the fork; ten vibrations of the fork occupying the same time as ten and one-half alternations of the current. If, then, K_1, K_2, etc., are the points at which the fork makes contact, it follows that ordinates to the current curve, at corresponding points, will indicate the strength of the current in the telephone, and consequently the intensity of the sound. The curve of which *XY* is an ordinate is, then, the "sound" curve, and there is one beat for every half period by which the current precedes or lags behind the fork. An inspection of the curve shows that if the frequency of the current were one-half as great, or one and one-half times as great as shown in Figure 2 (the periodicity of the fork remaining unchanged), there would again be no beats. Thus, as is in general the case, it is necessary to know approximately the periodicity which is to be measured accurately. It follows, further, that a given fork will measure periodicities other than those at which it is rated. If the fork, for example, has a range from 110 to 130 single vibrations per second, it will, as we have seen, measure periodicities ranging from 110 to 130 complete alternations per second. If, however, the

periodicity of the current were between 55 and 65, or between 165 and 195, the fork could still be adjusted for no beats, so that the same fork will serve equally well for measuring periodicities ranging within those limits.

As shown above, under the conditions where one single vibration of the fork is nearly equal in time to one alternation of the current, one beat occurs for every half period by which the current differs from the fork. Therefore, if the source of current is a dynamo giving 120 alternations per second, and the fork is adjusted for no beats, and the speed of the dynamo then changes so that there is one beat every five seconds, we know that the speed of the dynamo has changed by one alternation in ten seconds or by one part in twelve hundred. This suggests a method of measuring fluctuations in speed of any machine to which a small alternating generator can be attached: if applied to an engine, it would show the controlling action of the governor. For this purpose it would be necessary to so adjust the fork that its period would always be greater or less than that of the current; for if, when the periodicity of the current were fluctuating, the fork and current came sometimes into unison, there would be no convenient means of determining from the beats when they occurred, whether the periodicity of the current had increased or decreased. For continued observations it might be desirable to substitute for the telephone some simple recording device.

The method of driving the fork electrically is a modification of the method of W. G. Gregory (Phil. Mag., Dec., 1889, p. 490). The fork is magnetized with its prongs forming the north and south poles, between which is mounted an electro-magnet M (Figure 1). This magnet is connected to the secondary coil of a small ring transformer T, which has two primary coils P_1 and P_2, wound in opposite directions. A and B are mercury contact-makers connecting a storage cell E to the coils P_1 and P_2 respectively, and so adjusted that, at about the middle of the stroke of the prongs, the circuit is simultaneously closed in one and opened in the other. Thus, when the prongs are approaching each other, the current is flowing in P_2 until the prongs reach the middle of their stroke; at that point the circuit in P_2 is broken and that in P_1 is closed. The current in P_1 then reverses the magnetism of the core, inducing a momentary current in S which causes M to exert an attraction on the prongs N and S. When, however, the prongs are receding from each other the circuit is opened in

P_1 and closed in P_2, and the induced current in S causes M to exert a repulsion on N and S. The fork receives an impulse then at the middle of each stroke. Gregory uses but one primary coil on the transformer, and the fork is driven by the induced currents due to making and breaking the primary current. As, however, the change in magnetic flux in a soft-iron, closed-circuit transformer is more than ten times as great when the magnetizing force is reversed, as when it is simply removed, the modified method admits of the use of very much less current in the primary circuit. The core of the transformer was a ring consisting of 125 turns of No. 23 iron wire with a mean diameter of 8 c. m. The secondary coil consisted of 250 turns of No. 20 copper wire wound outside the two primary coils, each of which had 150 turns of No. 24 copper wire. Less than $\frac{1}{3}$ ampere was sufficient to drive the fork. Moreover, the use of two coils, together with the smaller current, reduced the sparking very materially, and, with a condenser C of 0.3 microfarad across the contacts, the sparking was scarcely perceptible.

ROGERS LABORATORY OF PHYSICS.
April, 1899.

Vol. XII. SEPTEMBER, 1899. No. 3.

TECHNOLOGY QUARTERLY AND PROCEEDINGS OF THE SOCIETY OF ARTS

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PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. XII. SEPTEMBER, 1899. No. 3.

PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTY-SEVENTH YEAR, 1898–99.

BOSTON, March 23, 1899.

THE 524th regular meeting of the SOCIETY OF ARTS was held this day at the Massachusetts Institute of Technology, with Professor George F. Swain in the chair. Sixty-eight persons were present.

The proceedings of the last meeting were read and approved. The Chairman then introduced Mr. Francis R. Hart, F. R. G. S., President of the Cartagena-Magdalena Railway in Colombia, Central America, who read a most interesting paper on "An American Railway in Colombia."[1] He described the great natural advantages of the port of Cartagena, and the richness of the country drained by the Magdalena River. This river is navigable for some seven hundred miles, and it furnishes a natural road over which the products of the interior may be transported. The Magdalena River flows within about sixty miles of the port of Cartagena, and as it has no good harbor at its mouth, a railway has been constructed between the river and the city by the company which operates the river steamboats.

The leading engineering feature has been the avoidance of high trestle bridges over the river beds by changes in the line to conform

[1] *Technology Quarterly*, June, 1899, pp. 123–134.

with the water divides, and the diversion of the smaller streams. Many interesting pictures were shown to illustrate the character of the country and buildings erected by the company.

A discussion followed. The meeting was then adjourned.

BOSTON, April 13, 1899.

The 525th regular meeting of the SOCIETY OF ARTS was held this day at the Massachusetts Institute of Technology with Mr. George W. Blodgett in the chair. Forty persons were present.

The proceedings of the last meeting were read and approved. Mr. Charles L. Norton, '93, Instructor in Heat Measurements at the Massachusetts Institute of Technology, and Mr. Osman S. Armstrong, Electrician, Riverside Press, Cambridge, were elected Associate Members of the Society.

The Chairman then introduced Mr. George L. Hosmer, of the Massachusetts Institute of Technology, who presented a paper on "The Middlesex Fells Geodetic Observatory."[1] This observatory is intended primarily to be used in giving instruction in the most refined methods of determining latitude and longitude, and secondarily to be used in magnetic and gravity observations. A description was given of the building and instruments, which include a transit of $2\frac{1}{2}$ inches aperture, 27 inches focus, a sidereal chronometer, chronograph, alt-azimuth, etc.

Observations have been made during the past term for the determination of time, and on latitude by Talcott's method. Arrangements have been made for the determination of longitude by telegraph connection with the Harvard observatory. The freedom of the observatory from vibrations, and its distance from magnetic disturbances, permits of much work that could not before be performed at any of the Institute buildings.

A discussion followed, and the meeting then adjourned.

BOSTON, April 27, 1899.

The 526th regular meeting of the SOCIETY OF ARTS was held this day in Room 22, Walker Building, Massachusetts Institute of Tech-

[1] *Technology Quarterly*, June, 1899, pp. 135–144.

nology. President Crafts presided. One hundred and fifty persons were present.

The minutes of the last meeting were read and accepted. It was voted, on motion of Professor Charles R. Cross, and seconded by Mr. G. W. Blodgett, that the President appoint a committee to nominate the Executive Committee for the ensuing year.

Mr. T. B. Kinraide, of the Spring Park Laboratory, Jamaica Plain, was then introduced and read a paper on "A New Form of Induction Coil." This unique form of induction coil of great power has been especially applied to the study of discharges by the aid of photographic processes, the plate being balanced on the top of the discharging globe in a dark room, and being developed after exposure to the light of the discharge. This process reveals in a striking manner the marked difference that exists between the positive and negative discharges. The apparatus was exhibited in operation, and photographic plates were shown by the lantern. The figures produced were of extraordinary beauty, and the delicacy of detail was brought out very clearly by the lantern.

A vote of thanks was tendered the lecturer for his very interesting and instructive paper. The meeting then adjourned.

ARTHUR T. HOPKINS, *Secretary.*

BOSTON, May 11, 1899.

The 37th annual meeting, 527th regular meeting, of the SOCIETY OF ARTS was held at the Institute on this day at 8 P. M., with Mr. Blodgett in the chair, and Dr. Bigelow as Secretary *pro tem.* Twenty persons were present.

The record of the previous meeting was read and approved. The Secretary read the Annual Report of the Executive Committee. It was voted that the report be accepted and placed on file.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

The first meeting of the SOCIETY OF ARTS for the present year was held on October 13, 1898. Fourteen meetings have been held, and the following papers have been read:

"Bacteria in Milk; Including their Rôle in Butter and Cheese Making," by Mr. S. C. Keith, Jr.

"Wool, with Practical Features that Enter into the Forming of a Wool Tariff," by Mr. Henry G. Kittredge.

"Metropolitan Water Supply," by Mr. Frederic P. Stearns.

"Geology of the Wachusett Reservoir," by Professor W. O. Crosby.

"Repeated Stresses," by Professor Jerome Sondericker.

"A Description of the Construction and Other Features of the South Terminal Station," by Mr. George B. Francis, and Mr. Henry J. Conant.

"Modern Methods of Steel Forging," by Mr. H. F. Porter.

"The Diesel Motor," by Colonel E. D. Meier.

"The Construction of the University of Virginia, Old and New," by Mr. Theodore H. Skinner.

"An American Railway in Colombia," by Mr. Francis R. Hart.

"The Middlesex Fells Observatory," by Mr. George L. Hosmer.

"A New Form of Induction Coil," by Mr. T. B. Kinraide.

"The Present State of Metallurgy of Lead in the United States," by Professor H. O. Hofman.

The meeting on December 22 was for the purpose of opening the new Pierce Building to the interested public.

A number of new members have been added during the year. At the close of the year 1897–98 the number of Life Members was 53. Five have died this year, leaving the present number 48.

The number of Associate Members a year ago was 323. Of these 1 has died, and 6 have resigned, but 17 have been elected, and the present number is 333. The Life Members who have died during the year are Hon. John Cummings,[1] Waldo O. Ross,[1] Henry Davenport, Hon. F. W. Lincoln, and Colonel Henry Lee. One Associate Member, Captain Alfred E. Hunt, of Pittsburgh, served in the war with Spain, and brought back his regiment without the loss of a man, but has just died from the effects induced by exposure in the trying campaign.

The Board of Publication of last year was reappointed, and the *Technology Quarterly* has been conducted as before, with Dr. Bigelow as responsible editor. During the year twenty articles have been published in the *Quarterly*, besides the Proceedings of the SOCIETY OF ARTS, and Review of American Chemical Research, which have appeared regularly. Of the contributed articles eight are papers that have been read before the SOCIETY OF ARTS, the remaining twelve having been presented by title only. Among the most notable of the latter is an extended paper by Professor S. W. Holman, entitled "On the Telescope-Mirror-Scale Method; Adjustments and Tests."

Respectfully submitted,

(Signed) GEORGE W. BLODGETT,
DESMOND FITZGERALD,
EDMUND H. HEWINS,
CHARLES T. MAIN.

There being presented no other reports from committees, nominations for officers for 1899–1900 were next in order.

The Secretary announced that the Executive Committee had voted to nominate Mr. Arthur T. Hopkins to be candidate for the office of Secretary. The report of the Nominating Committee appointed by the President, in obedience to the vote of the Society at the previous meeting, was read. The Committee nominated George W. Blodgett,

[1] See April number of the *Technology Review*.

Desmond FitzGerald, Edmund H. Hewins, Frank W. Hodgdon, and Charles T. Main to be members of the Executive Committee of the SOCIETY OF ARTS for the year 1899–1900.

A ballot having been taken, the Chairman announced that the candidates named above had been duly elected.

The following papers were presented by title:

"On Rapid Methods for the Estimation of the Weight of Suspended Matters in Turbid Waters," by Charles L. Parmelee and Joseph W. Ellms.

"On the Determination of Added Water in Milk," by A. G. Woodman.

"Assaying Telluride Ores for Gold," by Richard W. Lodge.

"Notes on an Unusual Orientation of Phenocysts in a Dyke," by M. L. Fuller.

"On a Method of Measuring the Frequency of Alternating Currents," by Harrison W. Smith.

Professor H. O. Hofman read a paper on "The Present State of Metallurgy of Lead in the United States." Attention was confined to the argentiferous lead ores of the Western States. The subject was treated under three heads: sampling, smelting, and desilverization. Sampling was formerly done entirely by hand, but now it is done largely by machinery.

The first argentiferous ores that were mined were chiefly oxides, and were smelted raw. Most of these ores were exhausted ten years ago. The ores that are being mined at present, as a rule, contain sulphur or arsenic, and must be roasted to drive off these elements before being smelted. Lead ores are roasted in reverberatory furnaces. Formerly the ore was moved by hand, but now this method is largely replaced by the employment of mechanical furnaces.

In smelting it is generally necessary to add a basic flux in order to obtain a good slag. The composition of slags was studied for the first time in 1870, and the greatest contributions to the theory of lead smelting have been made during the last twenty-five years. The products of the blast furnace are base bullion, spiess, matt, slag, and flue dust. The methods employed in the treatment of each of these products were described and the improvements noted.

The desilverization of base bullion is done by cupelling. A great improvement was made by the introduction of the preliminary Parks's method. This consists essentially in adding zinc. It results in the

formation of a silver-zinc-lead alloy which will float upon the lead and is easily removed, while the lead takes up very little of the zinc. The alloy is then cupelled.

A large number of lantern views were exhibited to show the various kinds of apparatus used in the metallurgy of lead, and the improvements that have been made in them.

There being no further business, the Society then adjourned.

R. P. BIGELOW, *Secretary pro tem.*

THE MANUFACTURE AND USE OF BREWING SUGARS IN AMERICA.[1]

By G. W. ROLFE, A. M., and GEORGE DEFREN, S. M.

Before proceeding with this subject it will be necessary to define what is meant by the term "glucose," as there is great variation in the use of this word and consequent confusion in the minds of many. In England and France, apparently, the term is synonymous with dextrose or starch sugar. In America the latter product is invariably called "grape sugar," "glucose" being applied exclusively to the thick, viscid syrup resulting from the partial hydrolysis of starch by acids, a familiar commercial product. In classifications of organic chemistry, the custom seems universal to use the word as a name for a sugar group, although quite recently the word "glycose" is being substituted in the interests of definiteness. In this paper we shall, in referring to the commercial products resulting from the acid "conversion" of starch, speak of solid sugar as "starch," or "grape sugar," confining the term "glucose" to the syrup previously mentioned.

The following outline of the chemistry of the acid conversion, or hydrolysis of starch, will make the details of manufacture more intelligible. When a thin starch paste is heated with a dilute acid, a change takes place much resembling in general appearance that caused by diastase. Investigation shows this difference, — the syrups converted by acid are made up of three components, maltose, dextrose, and dextrin; whereas, in the worts converted by malt (diastase) only two of these are found, maltose and dextrin. (We are speaking of those bodies resulting from the starch alone.) The conditions of formation of these carbohydrates in the two cases are radically different. The conditions of production of maximum maltose in worts, which never exceeds about 80 per cent. of dry substance, are defined by somewhat complicated procedure of heating at varying temperatures, considerable dextrin always remaining unchanged. In acid conversion,

[1] Reprinted from the Journal of the Federated Institutes of Brewing, Vol. V, No. 2, February, 1899. Read before the Society in Manchester, England.

on the contrary, within wide limits at any rate, the composition of the syrups follows fixed laws irrespective of the nature or amount of the hydrolyzing acid or the temperature conditions, these influencing the *rate* of change only. The amount of change at each stage of the conversion is shown by Figure 1, giving the percentage curves of each constituent, the stage of conversion being measured by the change in optical polarization of the syrup. It will be noticed that the original starch paste is pure dextrin, or to be more exact, corresponds in its properties to the primary carbohydrate we call dextrin,

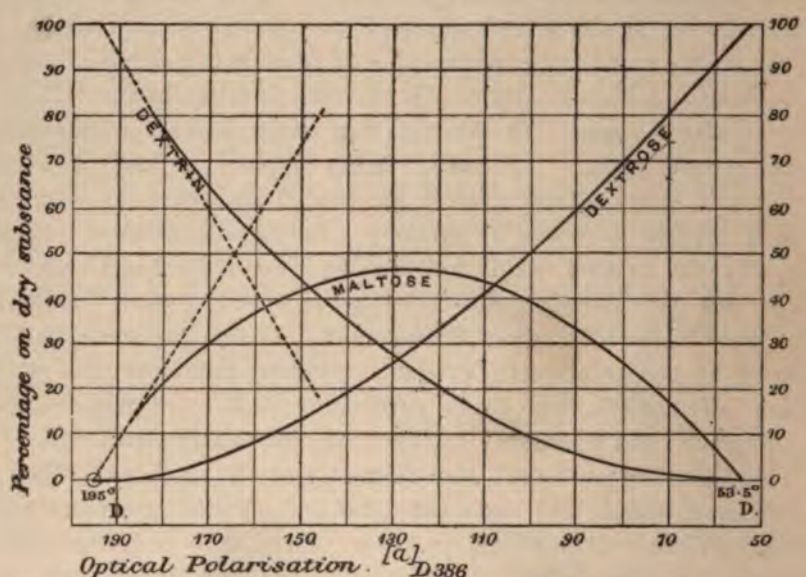


FIG. 1.—RELATIONSHIP OF PERCENTAGES OF PRIMARY CARBOHYDRATES TO OPTICAL POLARIZATION IN HYDROLIZED STARCH PRODUCTS.

(*Products of Diastase Conversion shown by Dotted Lines.*)

which must not be confounded with the commercial products or the alcoholic precipitates so termed, these being in reality complicated combinations. As the hydrolysis proceeds, the dextrin continually diminishes, maltose being rapidly formed, dextrose also appearing almost immediately but increasing at first very gradually.

At what may be considered the middle stage of the hydrolysis, the percentage of maltose reaches a maximum and then begins to disappear like the dextrin, but with more rapidity. Finally, dextrose alone remains in the solution, except some products of decomposition, present in very small amounts, unless the heat is excessive or the acid too

concentrated. The point of conversion for the manufacture of "grape sugar" is then clearly defined by this diagram. In the case of "glucose" two conditions are imperative: (1) The amount of dextrin must be sufficient to prevent the separation of crystallized sugar when the product is concentrated to 45° Bé., or about 84 per cent. (2) Under similar conditions dextrin should not separate out. These conditions limit the conversion stages to those represented by that part of our diagram lying approximately between the polarization figures, 150° and 100°. Commercial glucoses in the market vary in polarization from $[a]_{D\,386} = 145°$ to 120°. As the greatest consumption of glucose is in the manufacture of candies, jellies, and syrups, its composition has been determined by the demands of these trades. The use of glucose in beers, extensive as it is, takes a very small proportion of the total output. On this account there are practically two grades of glucose on the market, leaving out of consideration goods which differ only in concentration: Mixing (syrup) glucose, with a conversion of $[a]_{D\,386} = 120 - 130°$; and confectioners' goods of $[a]_{D\,368} = 130 - 140°$. The best confectioners' goods are commonly about $[a]_{D\,386} = 135°$. There is by no means a rigid standard in the market, however; in fact, many manufacturers grade according to the perfection of refining, the clearer, whiter glucose, independent of its conversion, being specially treated for confectioners' use. Jelly goods differ from mixing glucose merely in concentration, although imperfectly refined candy glucose is often worked up into this grade, as a slight turbidity or tint is of no consequence in jelly manufacture. Mixing glucose is the kind usually bought by the brewer. As we have stated, the composition may vary through wide limits, the proportion of dextrin, for instance, varying in extreme cases about 100 per cent. In short it should be well understood that commercial grading of a glucose is no criterion of the relative proportion of dextrose, maltose, or dextrin, matters of considerable moment to the brewer. The grading of starch sugars being more plainly conformable to the needs of the brewer, their chief consumer, we need not consider them here.

The time at our disposal will permit only the most superficial description of the manufacture of brewing sugars. In general the process consists of three parts: (1) Separation of the starch; (2) conversion; (3) refining. (The diagrammatic scheme (Figure 2) will assist in following this description.) All kinds of what is known as No. 3 or No. 4 corn (maize) are used, the market being the main consideration.

This corn is taken from the cars or the elevator of the works to the steep tubs, which hold 2,000 bushels or more. In steeping, water at 150° F. is used at first, then the steep is allowed to cool till a temperature of about 90° F. is reached. Sulphurous acid is used to prevent putrefaction and assist softening. The steeping lasts from three to five days. The separation of the starch consists of (1) grinding

FIG. 2.—SCHEME OF GLUCOSE MANUFACTURE.

the wet grain mixed with water, and softened by steeping; (2) separating the starch grains from the woody fiber and germ by washing through sieves of bolting-cloth, rapidly shaken; (3) settling out the starch from the gluten by subsidence while passing over gently inclined runs ("tables"). The grinding is done so that the starch grains are set free but not ruptured, an important point when yield is considered. The germ is removed separately in many factories, by a patented pro-

cess. This is accomplished by coarse grinding, and running the grain mixed with much water through a long trough, the mass being agitated slowly. The germ which floats is carried off by one channel, the rest of the grain by another. This separation of the germ is an important improvement, since the oil which is contained in it can be readily obtained as a by-product, and the quality of the glucose is much improved by its removal. The grain from the separators is ground and washed on the sieves ("shakers") in the usual manner, and the separated liquor sent over the runs. The thin, highly diluted gluten is allowed to settle, pumped through filter presses, and the dried cake, which contains over 30 per cent. of protein, sold for cattle feed.

The starch collected on the runs, and containing about 50 per cent. of moisture, is now mixed with water to a thick cream of about 20° Bé., preparatory to conversion. Conversion is carried on in large copper boilers at a steam pressure of 30 pounds, hydrochloric acid being the converting agent, the amount used being about 0.0006 of the weight of the starch.

In some factories sulphuric acid is still used as the hydrolyzing acid. In the manufacture of candy goods and certain hard sugars it seems to have some advantages. Oxalic acid has been used for the manufacture of fine candy goods, but the advantages gained are questionable. In the manufacture of grape sugar a much larger proportional amount of acid is used, in some cases up to 1 per cent. or more of the weight of starch. The point of complete conversion is usually controlled by the disappearance of the dextrin precipitate when the liquid is poured into alcohol.

In glucose conversion the acid is mixed with about fifty times its bulk of water, and is run into the converter. Steam is then turned on till a pressure of 30 pounds is obtained. This pressure is maintained while the starch milk is pumped in, which takes about half an hour. Heating is continued after this for 40 minutes or more. "Dirty" starch, containing much gluten, increases the time of conversion 10 minutes or more. The degree of conversion is entirely controlled by iodine tests. By daily practice workmen become quite expert in making these tests, yet from week to week there is apt to be considerable variation in composition when tests are not checked by chemical control, which is rarely the case as far as this point is concerned.

The refining process is in general similar to that of cane sugar.

The analogy is quite close in the case of the solid grape sugars. In the case of glucose, however, there is a radical difference of principle which must not be overlooked. In the refining of glucose the purification must be carried to great lengths, at least as far as color and appearance are concerned. All bodies affecting these characteristics must be absolutely removed from the liquid, or bleached in it, since there is no mother liquor in which they can be deposited, as in the case of a crystalline sugar. On this account the refining of glucose is a much more delicate process than that of sugar.

Neutralization is an important part of the refining, as on the thoroughness with which this is done depends how successfully the albuminoids, calcium and iron salts are removed. As soon as the conversion is completed the liquid is blown out into the "neutralizer," where the alkali, usually sodium carbonate, is added. In many factories it is the practice to cool the liquids considerably before neutralizing, but this seems unnecessary when the alkali is added properly. The liquid when neutralized should show only the acidity caused by carbon dioxide or the weakest vegetable acids. The properly neutralized liquid is clear and of a bright amber color, but contains large flocculent masses of coagulated gluten, which, in a test tube of ordinary size, form a layer about half an inch thick. When the proper point of neutralization is attained, this layer is greenish-drab, owing to the precipitated iron.

As in sugar refining, the precipitated matter is removed by bag filters, this often being supplemented by a press filtering. In the case of highly refined glucoses, precipitants are sometimes used, such as alum. The tendency seems to be for manufacturers not to push this part of the refining to greatest advantage, but rather to depend on a liberal use of bone-black to do much of what it would seem could be accomplished by less expensive means in preliminary clarification. The bone-black treatment is quite complicated, not only in the details of filtering but in the preparation of the black. Since the slightest trace of alkali in contact with the hot liquor will produce a brown stain of caramel, removable only to a limited extent by bone-black, the black itself must be freed from all traces of ammonia or caustic lime by a careful "tempering" with hydrochloric acid or some similar treatment, and subjected to a careful washing to remove soluble salts of iron and calcium. The glucose liquors are, as a rule, put over the bone-black twice; first at their original concentration, about 18°

Bé., and again after concentration, to 28 — 30° Bé., the denser syrup going over the freshly tempered black. The revivifying of the black is carried out on lines similar to those of cane sugar refining.

The "heavy liquor" goes directly from the filters to the vacuum pan in most modern factories. Formerly a preliminary filtration was necessary to remove the calcium sulphate which separated out, but with the use of hydrochloric acid conversions and neutralization with soda, this is avoided. In the final concentration sulphites are added in amounts varying from 0.008 to 0.050 per cent. SO_2.

The function of these sulphites is as follows: (1) To prevent oxidation and consequent coloration in the final concentration due to formation of caramel-like bodies, and sometimes ferric salts; (2) to bleach; (3) to prevent fermentation of the lesser concentrated finished products, as the thinner mixing syrups; (4) in candy goods, as a preventative of oxidation in the candy kettle. Confectioners' goods are much more heavily "doped" than others. There is a tendency among manufacturers to excessive use of sulphites in all classes of goods, a matter of some interest to the brewer.

The refining of grape-sugar liquors is practically identical with that of glucose. The concentrated syrups are drawn off into pans or barrels and allowed to solidify, a "seed" of crystallized sugar often being added to facilitate crystallization. Anhydrous grape sugar is made in a similar way from a syrup which is refined at lower concentrations throughout the process in order to obtain a purer product. In this case the "seed" is selected with the greatest care from absolutely pure anhydride, all hydrated crystals being scrupulously excluded. The crystallization is complete in about three days, when the sugar is purged in centrifugals. The purged liquors are often worked up into the "climax" sugars, a dark product familiar to most brewers. Of late years these sugars have been further refined as a white product, and even made directly by merely solidifying the anhydrous sugars as a concrete without purging. As is well known, these sugars also are often put on the market as "chips." Glucose syrups are usually made at six concentrations: 39°, 41°, 42°, 43°, 44°, 45° Bé. Mixing goods are usually finished up at 39° or 41° Bé.; 41° mixing glucose is the grade usually sold to brewers. The higher concentrated products are confectioners' or jelly goods, the former being characterized by greater perfection of refining and a large amount of sulphites. These are often whitened with methyl-violet.

A few words as to the manner of taking concentration determinations may not be amiss here, as there seems to be considerable confusion of ideas on this point. This is not surprising when we remember that there are over thirty different Beaumé scales in existence. The glucose manufacturers do not use the same scale as the sugar refiners, who employ Gerlach's modification. The glucose scale is practically identical with that used by the alkali manufacturers, and has the following conversion formula for the density: $d = \frac{144}{144 - Bé.}$ Owing to the great viscosity of glucose, the readings are taken not at the standard temperature of the instrument (60° F.), but at 100°. The determination is somewhat difficult and tedious. The slightly warmed glucose is poured into a cylinder, preferably of glass, which is placed in a water bath at 100° F. At the end of half an hour or so, the glucose will have reached the temperature of the bath, and the air bubbles will have escaped. A Beaumé spindle, reading to fifths, is then cautiously lowered into the glucose and allowed to come to equilibrium, which in the more viscous samples takes some minutes. With care the determination can be made on a Westphal balance. All samples of glucose should be tested for density, as the viscosity in goods of different conversions varies to a marked degree. A low converted sample of moderate density will apparently have much more "body" than a high converted glucose much more concentrated.

As, apart from concentration, the quality of commercial glucose is largely judged by its appearance, it will be interesting, possibly, to consider briefly some of the turbidities and colorations of the commercial products, their causes, and actual influence on the quality of the glucose. A well refined glucose is practically colorless and clear. If a white glass cylinder is filled with glucose, the color of the sample can be seen as well as any turbidity. If the color is a pure white, the sample is dyed, as can be proved by exposing it to the light for a few days, although this coloring is rarely done so well that a close inspection will not reveal the violet tint. As all glucoses darken slightly on exposure to the light, the color balance soon becomes disturbed, and the presence of the dye is made more evident. If no dye is present, the glucose, unless quite turbid, will show some color, usually green or yellow. These tints are almost invariably present, and seem to be caused by traces of iron salts and vegetable coloring matters. They are of little consequence, except as indicators of the thor-

oughness of the refining, and hence the removal of albuminoids and oil. These impurities affect the flavor of the product. Dyeing, therefore, likewise only concerns the brewer so far as it may be the means of compelling him to pay a high price for low-priced goods. A reddish-brown discoloration is the result of excess of alkali, as a rule either through imperfect neutralization or defective treatment of bone-black.

As to turbidity, cloudiness caused by faulty conversion, separation of dextrins in one case or sugar in the other, is in these days of rare occurrence. A smoky appearance is often caused by bone-black dust, or in some cases from iron sulphide, when a large quantity of new black is used in refining; these, of course, are the results of improper preparation of the black. White cloudiness is caused either by calcium salts or by organic growth due to fermentation. The former may be sulphate or phosphate. Sulphates in goods converted by hydrochloric acid are in the main introduced through use of impure acid, or in sulphite liquors; phosphates, from excess of "tempering acid," or incomplete washing of the black. The clouds due to fermentation, which naturally are more common in goods made in hot weather, are usually the result of storing thin liquor (in process) at too low a temperature. Of course the fermentation organisms can easily be identified by the microscope. A quick way of identification is to acidulate the sample with hydrochloric acid, when the ferment cloud remains undissolved. It is evident that the presence of foreign ferments possibly, even probably, in a state of activity, is a matter of no little concern to the brewer. Already attention has been called to this by Dr. Krieger, in an article in the *American Brewer* of September, 1896, on "The Use of Turbid Glucose in the Brewery." The author very properly advises a thorough boiling of such glucose in the wort. He, however, confines himself to finished goods which have fermented, presumably after they have left the factory, but often glucose to all appearances free from ferment will show presence of organisms as described. It would seem decidedly doubtful whether these organisms are entirely killed by the moderate temperature of the vacuum pan and the light treatment with sulphite which such goods often get.

While referring to this article of Dr. Krieger's, we may also call attention to an important paper by the same author, on "The Manufacture of Starch Products," in the *Zeitschrift für Spiritus-Industrie*, 1894.

It is evident that the calcium salts have no influence on brewing in the quantities present in glucose.

The valuation of the solid starch sugars is practically based on their dextrose content. Whiteness of late years seems to be more of a desideratum than formerly; hence the practice of dyeing is becoming common. The principal mineral impurity objected to is iron. This is rarely present in more than traces. A delicate test for iron in sugars or glucoses is made with cochineal. Sulphites must be first removed, and the solution made neutral or faintly alkaline. If iron be present, the pure crimson of the cochineal gradually passes into violet. We think in the past brewers have been more alarmed than injured by the iron in glucose. In the first place iron is only present in glucose in traces, never enough to cause damage in brewing; and secondly, if by any chance iron be present, probably it is precipitated in the form of tannate, which is removed in the "hop back," or through settling in the settling tuns. Moreover, most brewers will find that their brewing waters generally contain more iron salts than does any glucose, and also if they use iron mash tuns, or iron rakes in these tuns, some iron will always pass into solution by the action of the small amount of lactic acid in the malt, which would also be considerably more than that which occurs in glucose.

Our attention has been called to an iridescence on the surface of wort in the copper, containing much glucose. This was undoubtedly due to traces of corn-oil, which occasionally is present in finished goods.

We have omitted mention of any method of determining degree of conversion of glucoses, as we have already published this in detail (*J. Amer. Chem. Soc.*, October, 1896).

Solutions of grape sugar show the same characteristic colorations and turbidities, in a greater or less degree. Usually they show caramel tints, owing to the decomposition products, especially in inferior goods.

No exact statistics are at hand by which we can state with positiveness just what is the amount of brewing sugars made and consumed in the United States. The glucose industry uses about 35,000,000 bushels of corn (maize) annually in making about 1,000,000,000 pounds of glucose. As far as we can estimate, from 15 to 20 per cent. of this is consumed in brewing in the United States; about 160,000,000 pounds goes to England, a considerable portion of which, we understand, is used in candy making.

Apart from the foregoing brief account of the manufacture of commercial glucose and grape sugar, it is the object of the present article to show how these products can be, and in many cases are, used by lager and ale brewers.

There is a marked prejudice among brewers against the use of glucose as a substitute, yet these same brewers use large quantities of corn grits and corn flakes, forgetting for the moment that commercial glucose is really nothing more than common corn starch hydrolyzed by acids under steam pressure. This has been already explained in the first part of this paper, and shows that dextrose, in addition to dextrin and maltose, occurs in glucose, whereas diastase forms only these two latter from starch, the hydrolysis ending before the maltose is decomposed into dextrose.

Malt substitutes may be divided into two classes: those in which the extract is obtained by a mashing process with malt, and those in which the extract is already formed. The first comprises maize, rice, wheat, prepared corn, and corn flakes, etc. When using any of these substances for brewing purposes, certain proportions of them are either added directly to the malt in the mash-tun, or else the starch in these substitutes is first gelatinized in a separate vessel and rendered soluble by a little ground malt, and afterwards added to or sparged over the goods in the mash-tun. To the second class belong refined cane sugar, invert sugar, glucose and grape sugar, and refinery syrups.

These substitutes are used for some one or more of the following reasons:

1. Ease of manipulation.
2. Economy.
3. An improvement in, or changing the character of the finished beer.
4. Quick clarification.
5. Flavor.
6. Priming.
7. Pale beers.

1. When an ordinary pure malt wort has been prepared according to the established rules, it is simplicity itself to add glucose to this, either in the underback, copper, or hop back. The whole is mixed by boiling or stirring, and then fermented as usual. The amount of glucose or grape sugar to be added to the malt wort should be based upon

the same considerations as when using corn grits, corn flakes, and other similar substitutes. Glucose comes in barrels highly concentrated, and at once gives a maximum return for material used. No extract is lost through non-saccharification of any starch, as is the case with corn grits, etc. The only care to be exercised is that the barrel be steamed out, thus insuring complete removal of all glucose which might be attached to the staves. This is very much simpler than making a corn mash. It takes but a few minutes, requires no careful manipulation or expensive apparatus, and consumes but little steam. Another great advantage of glucose substitution is that the gravity of the wort may easily and quickly be brought to any desired stage — an advantage the brewer keenly appreciates, when through some mishap or change of malt he finds his wort several tenths of a per cent. below the accustomed gravity.

2. From an economical standpoint glucose and grape sugar are sometimes used, although at times the prices of these substitutes have been higher than malt or prepared grain, which would contain equivalent amounts of extract. A little more than a year ago American glucose was selling pound for pound of extract at less than half the price of malt. To-day the market conditions have placed the prices of glucose and malt on a more uniform basis, although it is still a decided economy for the brewer to use glucose at present quotations in combination with malt.

If brewers made a few calculations upon the price of the extract in glucose in competition with raw corn grits, prepared corn flakes, etc., they would easily save money at various times. There is no economy in purchasing 43° glucose at $1.60 (*6s. 6d.*) when corn grits sell at $0.96 (*4s.*) per 100 pounds; and yet we have brewers here who tell us they use glucose because it is the cheapest malt substitute obtainable, where if a little calculation were made, surprising results would appear.

3. There are many brewers who do not use glucose solely for reasons of economy. Glucose and grape sugar are used very extensively in America for the purpose of improving the finished beer. If used judiciously, there is no question that these substitutes improve this article. Glucose contains only a very small percentage of nitrogenous matter, and it has always been believed that the smaller the percentage of nitrogen in the wort the sounder it would be. This is a delightfully easy explanation, and we regret to say we do not believe

the statement entirely. Although this may apply when small amounts of sugars are used, and may have an important bearing on the subject, the amount of nitrogenous matter may be reduced to such small proportions that the beers are really thin in taste, and are derisively styled "corn beer," "glucose beer," etc., with considerable justice. Some nitrogenous (proteid) compounds in beer precipitate after standing or when cooled. In itself this may do no harm in affecting the taste, yet very few to-day wish beer so clouded with albuminoid turbidity that it is almost impossible to look through it.

It is here, then, that the addition of glucose is an advantage. A well refined glucose contains almost no nitrogenous matter, and when added judiciously, commensurate with the quality of malt used and the kind of beer desired, the results obtained well warrant the employment of this substitute. The wort obtained from poorly manufactured malt will not permit the use of much substitute, whereas a fine malt wort may have as high as 30 to 40 per cent., or even more, glucose added to it without endangering the quality of the beer. Many lager beer brewers use as much substitute as this in their wort and derive good results. On the other hand, the beer must have a certain "full-bodied" taste and retain its foam-keeping qualities, and one of the easiest ways of failing in these requirements is to add too much grape sugar or glucose. We know of one case where the amount of glucose was 65 per cent. of the entire raw material used, and although what was called "beer" resulted, people are usually fastidious enough not to desire any more of it. Beer is not simply a fermented glucose solution.

Many brewers say they wish their wort brewed at 12, 13, or 14 per cent. Balling. If it possess this percentage of extract their wishes are satisfied. The composition of the wort and the dependent degree of attenuation of fermentation troubles them but slightly. Yet beer may have a large percentage of extract, and still be thin in taste; while there are beers with 1 or 2 per cent. less extract, which possess a better head of foam, are more full-bodied than heavier articles, and are considered better in quality in every respect. Each brewer must use such amounts of glucose or grape sugar as he finds his trade will warrant.

There is another matter which should be touched on here, and that is, the choice of kind of glucose, as the following examples will indicate. A malt wort mashed at a low initial heat and brought up slowly

to a tap heat of 163° F., with a gravity of 10 per cent. Balling, if mixed with a glucose of a specific rotatory power of $[a]_{D386} = 145°$ until the gravity were 14 per cent. Balling, and then fermented, it would have about $1\frac{1}{2}$ per cent. more extract in the finished beer, and conversely less alcohol, than if the malt wort were mixed with glucose of $[a]_{D386} = 120°$ specific rotation, and brought to the same gravity. The difference would be even more marked if the finished wort were made up of 4 per cent. grape sugar of a rotation of 70°, in which case the amount of extract in the finished beer would be small, and the percentage of alcohol correspondingly high.

This is accounted for as follows: A normally converted glucose of a rotation of $[a]_{D386} = 145°$ contains, in dry substance, about 40 per cent. dextrin, 17 per cent. dextrose, and 43 per cent. of maltose. The dextrose ferments quickly, while only a part of the malto-dextrins is decomposed, these complex dextrins not fermenting until broken down by the action of the invertase of the yeast. A glucose of 120° specific rotation would, on the contrary, contain only 21 per cent. of dextrin, 34 per cent. of dextrose, and 45 per cent. of maltose in the dry substance; while a highly converted glucose — in other words, commercial grape sugar — of 70° specific rotation would have its dextrin reduced to about 2 per cent., while the amount of maltose, dextrose, and decomposition bodies, gallisin, etc., would constitute the remaining 98 per cent. The importance of an intelligent examination of the glucose is evident, for on this selection the composition of the finished beer will largely depend, especially when the amount of substitute is added with a liberal hand. Therefore a glucose should be selected and its delivery insisted upon, which will give a definite result. We are optimistic enough to believe that the day is coming when the brewer will state whether he wishes the glucose of a specific rotation of 145° or of 120°. One could be made about as easily as the other, and though they may look alike, still the results obtained by using them side by side would be decidedly astonishing in the finished product. The mixing and confectioners' trades have been the means of placing the glucose of to-day on the market, and the brewers simply take what is set before them.

By employing higher mashing heats, and adding a higher converted product, *i. e.*, grape sugar, we obtain a finished beer which possesses nearly the same percentage of alcohol and extract as a beer made by low mashing heats, to which low converted glucose of 130–135° spe-

cific rotation has been added. This is explained by the fact that high mashing heats cause the diastase of malt to act on starch in such a way that the amounts of maltose formed are small in comparison with dextrin, as has been so clearly demonstrated through the brilliant researches of Messrs. Brown, Morris, Heron, and O'Sullivan. If grape sugar be added to this, the amount of fermentable material necessarily increases, the percentage of alcohol also increases, while the extract diminishes. An analogous explanation would apply to the use of low mashing heats and low converted glucose of, say, 130° rotation.

To use sugars without reducing the stability of the wort, they should possess nearly the same compositions in malto-dextrin and fermentable sugars as the original wort made entirely from malt. There is no question that grape sugar, 70° rotation, is most advantageously employed in the manufacture of stock ales, as the percentage of dextrose in this substitute is very high and it is easily fermentable. Stock ale, to keep well, should be highly attenuated, *i. e.*, the beer should contain a large percentage of alcohol and a small percentage of extract, and that of a composition not easily broken down by the ordinary brewers' yeast. There are brewers here who, in using a low initial mashing heat, employ a small amount of glucose of 130° rotation, and report no harmful effects; but the majority of ale brewers prefer to use a higher mashing temperature and add more grape sugar instead, a process which gives very satisfactory results.

The ale and lager beer brewing industries have been aided within the past few years by the use of so-called "carbonators." These artificially charge the "still" ale or beer with carbonic acid gas, which gives it "life." Beer that has been thoroughly fermented, cooled, filtered, carbonated, and then bottled, though a comparatively rare article to-day, will surely become common before many years go by. A carbonated stock ale made by ordinary methods, and with the addition of grape sugar or high converted glucose, should make a very palatable article.

4. What has been said in the preceding paragraphs has a bearing on the fourth condition, that of clarification. Clarification in sugar-brewed beers, *i. e.*, beers in which high converted grape sugar is added, is quicker than in all malt beers. This is probably on account of the reduction of the viscosity of the wort, owing to the substitution of the dextrin and malto-dextrins, by fermenting the sugars, which causes

a more ready elimination of the yeast, as well as a more advantageous action of artificial finings when used in the "chip" casks in lager beer manufacture, and even in ales which are to-day treated after the main fermentation, very much as ordinary lager beer.

Bright, sparkling, draft ale is very much desired at the present day, and it is essential to have the fermenting wort clarify quickly. This is easily accomplished by simply employing grape sugar or high converted glucose of 100–110° rotation. The dextrose ferments rapidly, the solution becomes less viscid, the yeast is eliminated more easily, and filtration becomes simpler. This is very advantageous in bottling beers, which should be free from turbidity, in that the addition of glucose or grape sugar has reduced the amount of nitrogenous matter to a minimum, thus requiring less to be removed by cooling.

It was formerly claimed that the yeast would degenerate if glucose were put into malt wort on account of diminishing the nitrogenous matter. This has been proved entirely fallacious by practical experience. It has been shown that yeast can ferment considerably more sugar in wort than it is called upon to do on the average, although a limit must eventually be reached beyond which the yeast will not act. Yeast does not decompose sugar into alcohol and carbonic acid gas indefinitely without some additional nourishment, and this necessarily implies a certain quantity of nitrogenous matter in the fermenting wort. Quick clarification by the addition of grape sugar should not be too diligently sought, to the detriment of the life of the yeast.

5. A pure malt beer is prized by many. It generally possesses a good head of foam, is full-bodied, and is characterized by a distinctive flavor. It was at one time believed that foam-holding capacity and full-bodiness were due to dextrinous compounds, but this idea has died out. It is to-day considered that peptones and albumoses are the real causes of foam-keeping and full-bodied taste, and if mashing be carried out so that peptones are formed in maximum quantity, the amount of sugar substitute can be considerably increased without hurting the beer. The distinctive character of stock ale is obtained by fermenting wort to a low gravity, thus increasing the amount of alcohol to a maximum, and reducing the extract. The percentage of alcohol in beer depends on the amount of fermentable sugars present. If this be high, the alcohol percentage is high, and *vice versa.* Grape sugar consists almost wholly of dextrose, which is entirely fermentable, and when this is added to malt wort and fermented, the

percentage of alcohol rises, and gives to the stock ale its peculiar tart flavor. This is the real reason for its employment in stock ale. Mild running ales, pale ales, and pale lager beers, on the contrary, have generally a lower percentage of alcohol, and it is in their preparation that glucose syrup is added as a substitute.

6. The subject of "priming" is pretty well known to the average brewer. So-called "kräusening" in lager beer consists in injecting about 10 per cent. of a vigorously fermenting wort into the storage lager beer in the chip cask; whereas "priming" is simply an addition of a grape sugar solution to the storage ale which is then bunged down. The sugar present ferments, thus forming alcohol and carbonic acid gas; the latter impregnating the ale, gives it the requisite "life." Grape sugar is preferable to glucose syrup in priming, on account of the quick fermentation without prolonged decomposition, as is the case with glucose.

7. Glucose and grape sugar are very extensively used in the United States for pale beers. The American people have become so accustomed to drinking light beers, that a very great demand has been created for them. Dark beers are not much desired. In manufacturing pale beers the brewer demands malt kilned at a low temperature, and adds to this a considerable quantity of substitute, be it corn grits, corn flakes, or other corn product, rice, etc. Glucose is added directly to the wort in the copper, and then fermented as usual. The ordinary malt wort possesses a very considerable amount of color, even if the malt employed has been dried at a very low temperature. A glucose or refined grape sugar solution, on the other hand, is practically colorless, and when added to the malt wort necessarily gives the article a much lighter appearance. An attractive beer is as essential as a palatable one, and where a good appearance and a fine flavor are combined, the brewer's labors are accomplished.

In conclusion, we would say that we hope these somewhat fragmentary notes on the manufacture of glucose and grape sugar, and their application to brewing purposes, will accomplish their sole object; that is, a more extended discussion and study of these useful materials, carried on with the conscientiousness and thoroughness which their importance deserves.

APPARATUS FOR TESTING INJECTORS.

By CHARLES FRANCIS PARK, S. B.

Received August 4, 1899.

The difficulties in obtaining correct injector tests are realized by all who are familiar with these instruments. Several methods of testing are in use, but all have properties that are apt to lead to unsatisfactory results. So, in whatever method we may adopt, there will be present some objectional feature; and in the design of the apparatus described in this paper, the method of testing which was selected was the one whose difficulties could be overcome with the maximum accuracy.

As this paper will be of interest to those only who are somewhat familiar with the testing of jet apparatus, or the like, no discussion of the action of the injector nor of the several methods of testing that are in use will be given; and I will proceed at once to describe the apparatus that has been designed and placed in the Engineering Laboratories of the Massachusetts Institute of Technology.

The problem before us is to obtain the amount of water pumped, the steam used, the time occupied, and the conditions under which the injector has done this work, namely: the pressure of the steam used, the quality of this steam, the pressure under which the water was delivered, the height through which the water was lifted, or the suction, and the temperature of both the suction and the delivered water.

The quantity of water pumped is found by measuring both the suction and the delivered water by direct weight. The amount of steam used for the given time is the difference in weight between the delivered and the suction water for the same time, as the delivered water contains the steam used, condensed. The conditions of working, under which these quantities have been determined, are obtained in a manner clearly shown by the description of the apparatus.

The injectors have been mounted and piped in such a way that a test can be run on either one without any change of the connections other than the manipulation of two valves. Steam is supplied to the

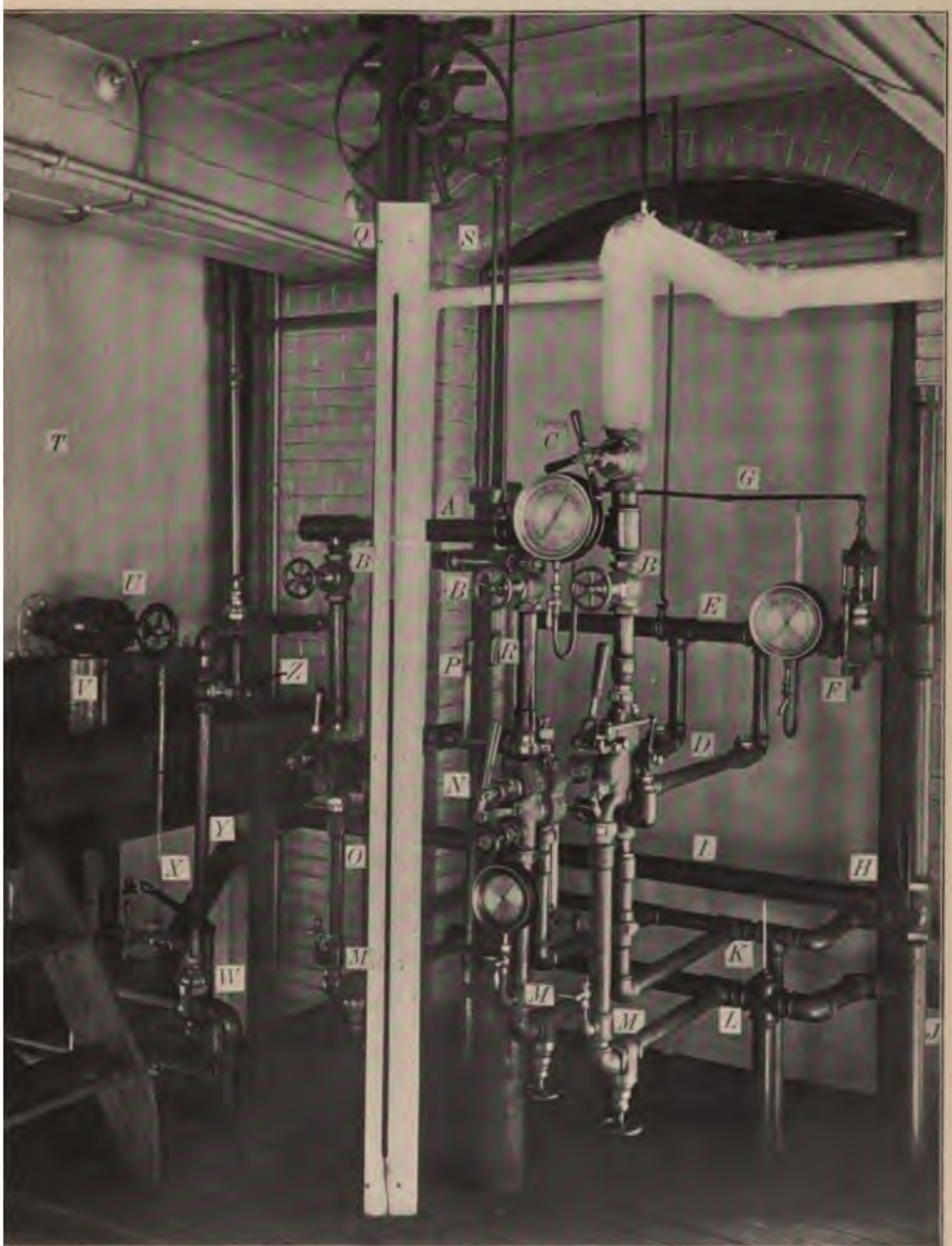


FIG. 1. — APPARATUS FOR TESTING INJECTORS.

injectors (Figure 1) from the pipe *A*, through the branch pipes and valves *B*, one of the latter being opened for the injector to be tested. A gauge connecting with the pipe *A* gives the pressure of the steam, which pressure is regulated by the throttling valve *C*. A throttling calorimeter (not shown in the figure) can be connected with the steam pipe *A*, and the quality or priming of the steam thus ascertained.

The delivered water passes through the branch pipes and check valves *D*, into the delivery pipe *E*, the pressure of the delivery being maintained in this pipe by the back-pressure valve *F*. The pressure of the delivered water is taken by a gauge connected with the pipe *E*, and a thermometer inserted in this pipe gives its temperature. A second thermometer is usually hung near the first in order to apply a correction for stem exposure.

The back-pressure valve *F* has been designed to automatically hold the delivery pressure equal to the steam pressure, or a little in excess of it for whatever variation there may be in the latter. The construction of this valve is shown by Figure 2. It will be noticed that the valve stem has been extended, and that it carries at its upper end a piston which presses against the under side of a rubber diaphragm. Above this diaphragm is a small chamber which is filled with water and connected with the steam pipe *A* (Figure 1) by a small pipe *G*. There always exists, then, in the chamber a pressure equal to that in the steam pipe, and this pressure, acting through the diaphragm on the piston, places a load on the valve stem that holds the valve disc to its seat. Now, if the area of the piston is equal to the area of the valve opening, a pressure will have to be created in the delivery pipe equal to that in the steam pipe before the valve can be opened. Thus, this valve will hold the delivery pressure equal to the steam pressure, as any variation in the latter will result in a corresponding change in the load on the valve disc. As the size of the valve is large in comparison with the size of the injectors, and as it throttles to a high pressure, the valve movement is very small and hardly perceptible.

In reality an injector when feeding a boiler is required to work against a delivery pressure a little in excess of the steam pressure on account of friction, resistance of valves, etc., so we have made the piston of the back-pressure valve a little larger than the valve opening to meet this condition.

If it is desired to run a test with the delivery pressure considerably in excess of the steam pressure, an additional load can be placed

on the valve disc by the use of dead weights, which can be hung on a yoke that is attached to the valve stem clearly shown in the figure. The ultimate pressure of delivery, or the pressure against which the

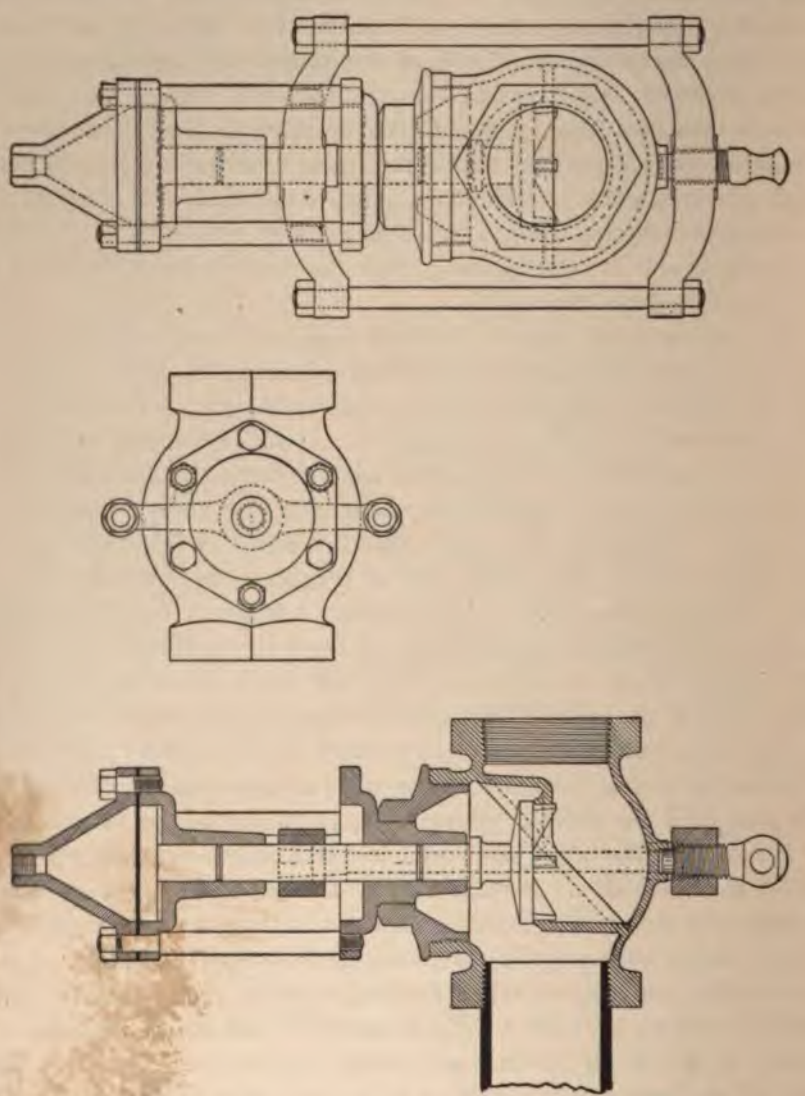


FIG. 2.—2½" BACK-PRESSURE VALVE.

injector fails to work, can be found by setting up a screw at the bottom of the valve yoke, which will draw the valve disc to its seat and increase the pressure until failure.

The delivered water after leaving the back-pressure valve passes through a three-way cock *H* (Figure 1). This three-way cock causes the water to flow either through the pipe *I*, which is a waste pipe, or through the vertical pipe *J*, which empties into weighing tanks on the floor below. To prevent a loss in weight of the delivered water by evaporation, a cooler has been placed on the delivery pipe *J*, and the weighing tanks are kept covered.

The overflows of the injectors are connected by branch pipes to one main overflow pipe *K*, which leads to a separate weighing tank. The waste through the overflow during a test is collected in this overflow tank and weighed.

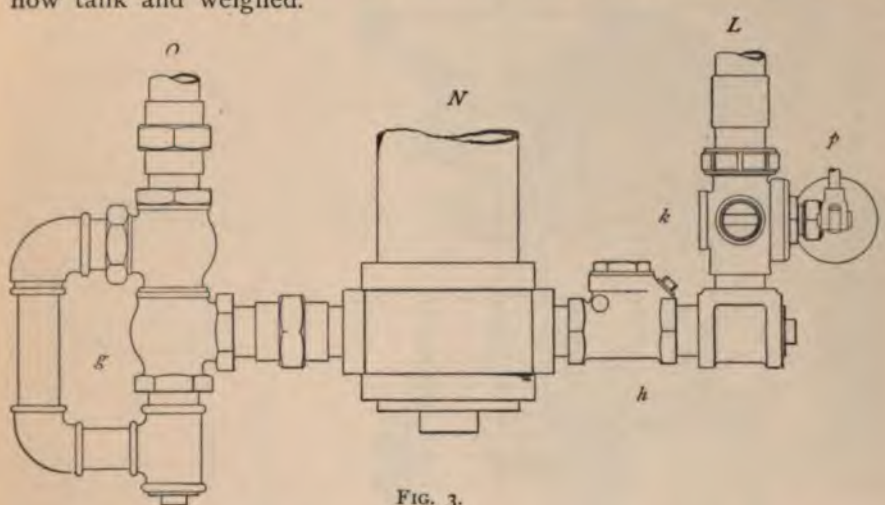


FIG. 3.

The suction pipe *L* is connected to the injectors through the branch pipes and gate valves *M*, one of which must be opened for the injector to be tested. The suction water is drawn from a 6-inch standpipe *N*, the connection being made at its lower end. This connection is shown in Figure 3.

The feed water is supplied to the standpipe *N* by the supply pipe *O*, the supply being controlled by a balanced valve *g*, the action of which will be considered later. This feed water passes from the standpipe to the suction pipe *L* through a check valve *h*, and a three-way cock *k*. This three-way cock *k* is of a special design, and is inserted here to furnish means of emptying the standpipe and adjusting the lift. The construction of this cock is shown by Figure 4. It will be noticed that it gives a full opening to the suction pipe in one position

(the position when running the test), and that when thrown in its other position it connects both the standpipe and the suction pipe with a

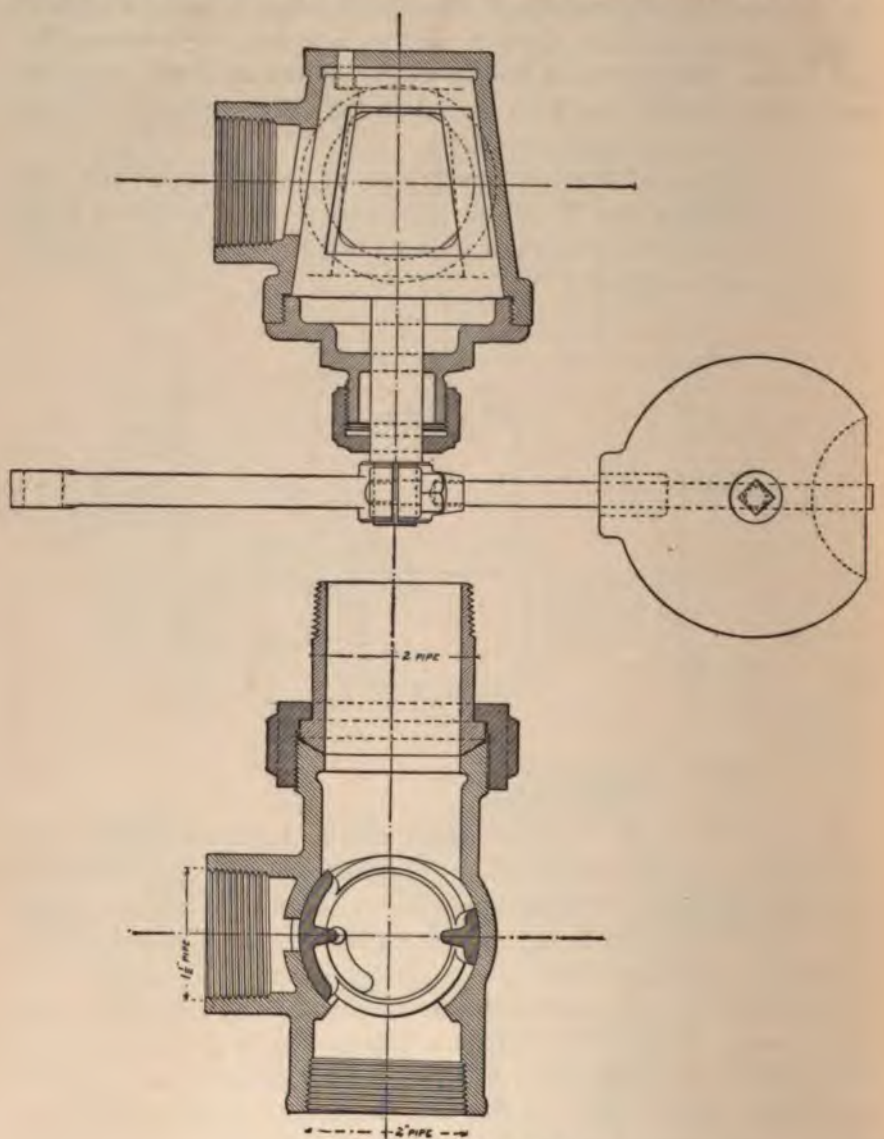


FIG. 4. — THREE-WAY COCK.

third pipe, which is a waste pipe. It is operated through a rod *p*, and a system of levers by the handle *P* (Figure 1).

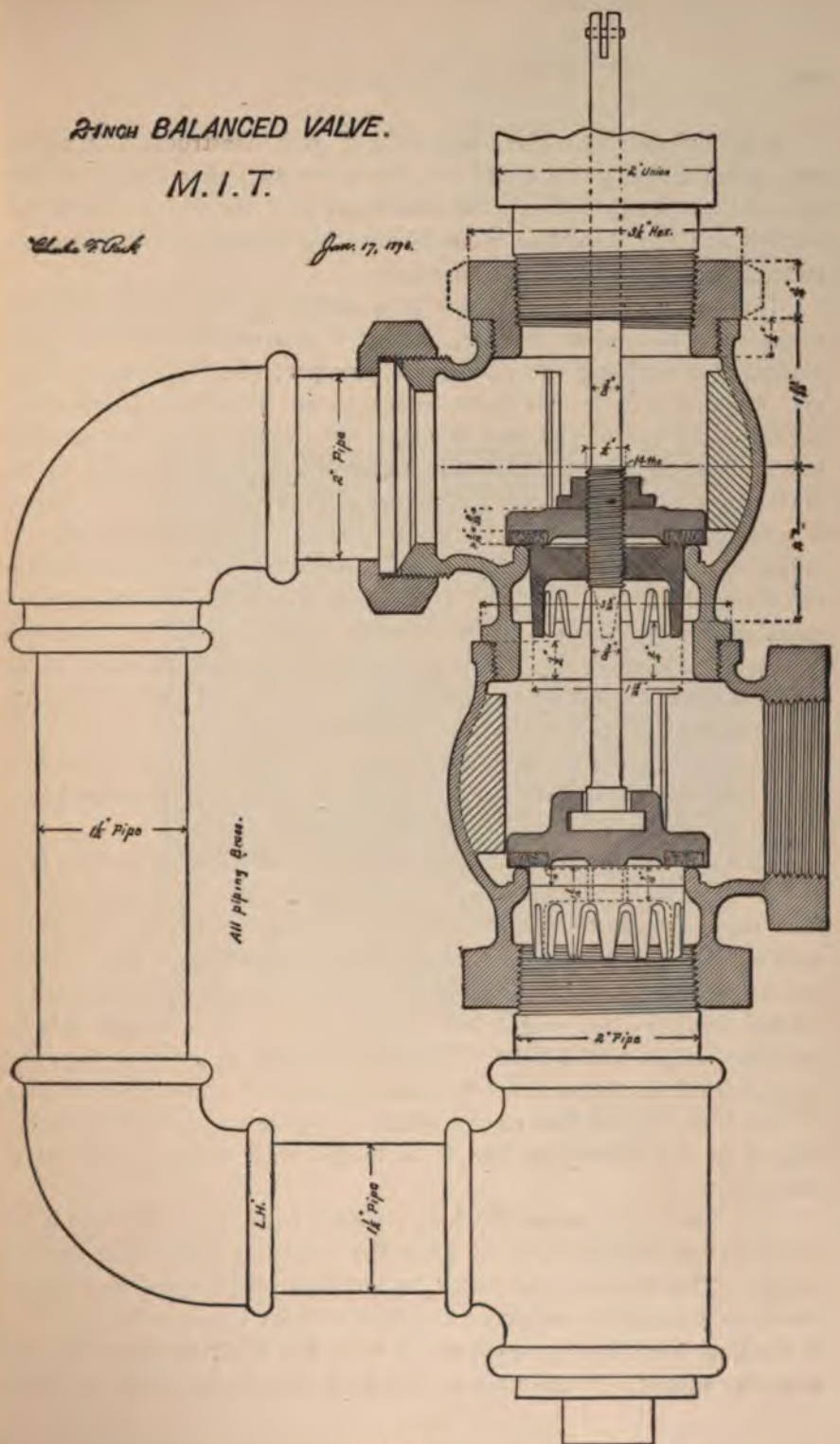

2 INCH BALANCED VALVE.
M.I.T.
2" Union
3¼" Hex.
2" Pipe
1¼" Pipe
All piping Brass.
2" Pipe
L.H.
1¼" Pipe

FIG. 5.

It is obvious that a three-way cock of such construction is necessary, as an ordinary one would cut down the suction opening on the run, and would connect only the standpipe with the waste. Both the suction and the standpipe must be emptied together. Otherwise a starting test for lift cannot be made.

The balanced valve *g* (Figure 3) is shown by Figure 5. Its construction is somewhat peculiar, in that it was made from two globe valves, thus avoiding the making of new patterns. The valve discs are provided with leather seats, and both are attached to one stem. To the upper end of the stem is connected a chain which operates the valve. The only feature that may not be clearly seen from the figure is the serrated disc that is placed under each valve disc proper. These discs are made to nearly fill the valve opening, and are tapered off and serrated to within about one-half an inch of the valve seats. Without these discs it is clearly seen that the valve when running a minimum supply would be open only a very small amount, and would in consequence chatter or pound and give trouble. By the use of these serrated discs, the valve must be raised a considerable amount from its seat before an appreciable flow can be maintained.

The level of the water in the standpipe is controlled automatically by a float which acts on the balanced valve through the regulating device shown in Figure 6, and also in Figure 1.

This device is hung from the ceiling, and consists of a shaft that carries two pulleys and a gear, each fixed to it, and two loose levers. The pulleys serve as drums. The larger one holds a flexible brass wire cord that connects with the float in the standpipe. The smaller one holds a fine steel wire, to which is hung an iron weight that moves up and down in the weight box *Q* (Figure 1). This weight acts as a counterweight to the float. The float is made of sheet copper, and is cylindrical in shape, about 5 inches in diameter and 12 inches long. It has four vertical fins on its outside to prevent it from becoming lodged in the standpipe, and it is loaded with shot to the proper buoyancy.

The float cord leaves the larger pulley from the right-hand side, and the counterweight is hung from the left-hand side of the smaller pulley. The counterweight with its small leverage is not sufficiently heavy to balance the weight of the float with its larger leverage. So, if the float were free to fall it would turn the shaft to the right and raise the weight. If the float were raised, the weight would keep the

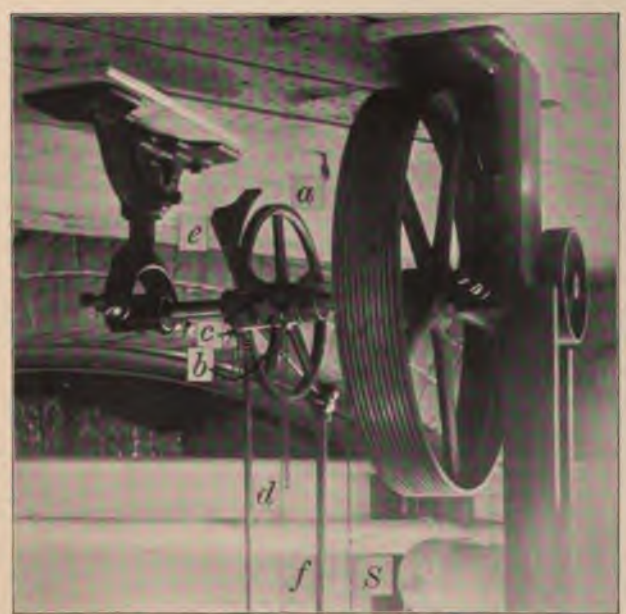


FIG. 6. — AUTOMATIC REGULATOR.

float cord taut and turn the shaft to the left. Now as the float moves with the water level in the standpipe, any change in this level will cause the shaft to turn in either the one or the other direction. The counterweight, then, will move with any such change, and can be made to serve a double purpose; so an index has been fixed to it which will register on the graduated scale of the weight box the water level in the standpipe or the lift. The water level can also be ascertained by gauge glasses that are connected with the standpipe at fixed intervals. These gauge glasses furnish means of graduating the scale on the weight box, and also serve as a check on this scale. An adjustment can be made at any time by a turn-buckle that is attached to the weight for such a purpose. A helical groove (or a coarse square thread) has been cut on the face of both pulleys for the cords to run in, so they will not be wound on themselves, and thus prevents any change in the effective diameter of the drums.

The gear *a* (Figure 6) acts as a ratchet wheel, and works the lever arm *b*, through a pall *c*, carried by the arm. To this arm is fixed a brass chain *d*, that is attached to the stem of the balanced valve. Now to hold a constant water level in the standpipe, water must be admitted as fast as it is withdrawn. This is accomplished automatically as follows: Suppose the water level falls, then more water must be admitted; but when the water level falls the float moves with it and turns the shaft to the right. The gear, then, turning to the right with the shaft, will move the arm by means of the pall, in the same direction, and cause the chain to raise the valve and admit more water. If the water level rises, then the float rises and the counterweight will turn the shaft to the left. This movement of the shaft and gear to the left will allow the arm to fall and the valve closes by its own weight.

The closeness with which this device will regulate depends upon the resistance of the mechanism to motion. That is, if it requires a pull of 2 pounds to work the valve, the water level could change until the float had displaced about 1 pound of water (on account of the difference of leverage) before the valve could be moved. In reality the resistance is very small. There is no stuffing box on the valve stem, the supply pipe *O* being screwed to the valve in the place of its bonnet, and extended in height above the top of the standpipe so it can be left open. The chain *d*, then, can pass through the supply pipe and be attached directly to the valve stem. The pull now on the

chain necessary to raise the valve is very slight, as it has only to overcome the weight of the valve, which is very small, being submerged. The resistance of the shaft to turning is also very slight, as the boxes in which the shaft turns are provided with ball bearings. The resistance of the whole system is so small that the mechanism will hold the water level so nearly constant that no change of its level is perceptible in the gauge glasses. The necessity of holding this water level constant will be obvious later.

The water level can be set for any lift between 0 and 25 feet at intervals of $\frac{1}{4}$ of an inch, by placing the pall *c* in the different teeth of the gear *a*; the difference of a pair of teeth giving a difference of water level in the standpipe of about $\frac{1}{4}$ of an inch. The lift can be changed or set as follows: To decrease the lift, the balanced valve can be opened and made to admit more water by the handle *R* (Figure 1), which is on an arm of a bell-crank lever that is connected by a chain *S* (Figures 1 and 6) to an arm of the lever *b*, which operates the valve. To increase the lift, the standpipe can be split by opening the three-way cock *k* (Figure 3). This cock is operated through a system of levers and rods by the handle *P* (Figure 1). Now it is apparent that as the water level falls the float will turn the shaft of the regulating device to the right, and perhaps cause the balanced valve to admit water as fast or even faster than it is withdrawn. To prevent this, a second lever *e* (Figure 6) which carries a shield on one of its arms has been provided, and this shield, if the lever is swung to the left, will throw the pall out of the gear. Now the rod *f*, which works this lever, is attached to the same lever that operates the three-way cock *k*, so that the handle *P* (Figure 1) will throw out the pall *c* (Figure 6) before the three-way cock is opened, and the shaft will then be free to turn without moving the lever *b*.

The supply pipe *O* (Figure 3) is supplied with the feed water from the tank *T* (Figure 1). This water is admitted by the value *U* to the chamber *V*, which leads to the supply pipe *O*, through the drop-valve *W*. A gauge glass *X* gives the water level in the chamber *V*. The feed water tank *T* rests on scales and is weighed before beginning the test. As the injector must be running before the test is begun, a second supply is obtained through the pipe *Y*, this supply being governed by the valve *Z*.

A test is started as follows: Start the injector, supplying the standpipe through the pipe *Y* and valve *Z*. Have the three-way cock

H thrown down, the delivered water running to waste through the pipe *I*. Set the lift and weigh the empty delivery and overflow tanks, the feed water in tank *T* having been previously weighed. Now, at a preparatory signal (say 5 seconds before the start) close the valve *Z*. This shuts off the water supply, but the chamber *V* is large enough to take care of it until water can be drawn from the tank *T*. At the starting signal close the cock &, the three-way cock *H* being thrown at the same time. As these two motions are similar, there is no reason why two persons cannot make them at the same instant, which gives a correct start for both the suction and the delivered water. Throwing the three-way cock *H* sends the delivery water to the weighing tanks. Thus these weighing tanks receive no water until the test is begun, and it is taken from them in the same manner when the test is ended.

When the cock & is thrown it locks the water into the gauge glass *X*, and setting an index on this level, the amount of water in the chamber *V*, or in the whole system at the start of the test, is determined. After this index is set the cock & can be opened again, and water can be drawn from the tank *T*. Now if the test is stopped with the same amount of water in the chamber *V* as at the start, the amount of water drawn from the tank will be just the amount of suction water used, provided there remains in the whole system the same amount as at the start, which will be the case if the water level in the standpipe is the same.

To stop the test, with the same amount of water in the system as at the start, proceed as follows: At the preparatory signal, shut off the water supply from the tank *T* by closing the valve *U*, care being taken that the water level in the gauge glass *X* is not much above the index. Now at the final signal close the drop-gate valve *W*, the three-way cock *H* being thrown at the same instant. The valve *W*, being closed, has locked into the chamber *V* all water that it held at the end of the test, and now sufficient water can be drawn from the tank *T* to bring the level up to the index which was the water level in the chamber at the start of the test.

To insure no leakage by the valve *Z* during the test, a gate valve has been placed back of it. After the test is started this gate valve can be closed, and a drip cock between the two valves can be opened.

It is understood, of course, that observations have been taken throughout the test for the pressure of the steam, the pressure of

the delivery, the lift or suction, and the temperature of the suction, and the delivered water.

With this method of determining the amount of steam used by the difference in weight of the delivered and the suction water, great accuracy and precision are necessary, as an error of 1 per cent. in the determination of either the delivered or the suction water would result in an error of nearly 10 per cent. in the quantity of steam used. Hence, the necessity of employing the delicate mechanisms and the special devices that have been used in this apparatus is apparent

CONTRIBUTION FROM THE LABORATORY OF SANITARY CHEMISTRY.

I.

ON NITRITES AS A PRODUCT OF COMBUSTION.

BY EDWARD W. AXSON, M.A.

THE experiments here described were undertaken in continuation of the work of Mr. George Defren,[1] who showed that when pure water was left exposed in evaporating dishes to the air of rooms in which gas had been burning, the water so exposed gave when tested for nitrites, a reaction which varied in intensity approximately with the length of the exposure. Mr. Defren tried also a quantitative method similar to that ordinarily used for carbon dioxide in rooms, namely, drawing the air to be tested into 8-liter bottles, and absorbing the nitrites by introducing 100 cc. pure water, and allowing it to stand 12 hours.

The question of nitrites in the air has received a good deal of attention from various chemists, a brief account of whose work may be found in an article by Alfred von Bibra,[2] and a more complete list of references on the subject has been prepared by Mr. Defren in the article already referred to.

The main facts are as follows: Schönbein and Loew stated that active combustion was accompanied by the formation of ozone (in addition to carbon dioxide and water) which could be detected by its odor and by its reaction with starch and potassium iodide. Böke, however, disputed their assertions, claiming that the reactions observed were due to the higher oxides of nitrogen and not to ozone. W. V. Hoffmann showed that the gas so obtained was reddish in color, and had an odor like that of nitrous acid; and Zoeller and Greete proved conclusively, by burning purified hydrogen in purified air, that it was nitrous acid. Rubner and Cramer have made quantitative determina-

[1] *Technology Quarterly*, IX, Nos. 2 and 3, June and September, 1896.
[2] Archiv für Hygiene, 15, 216.

tions of this acid, using the ordinary methods of absorption by bubbling the products of combustion through some absorbent. Rubner used for this purpose a solution of barium hydrate contained in a Schlösing absorption apparatus, while Cramer employed pure water in a flask chilled with ice.

This subject derives its interest from the fact that the nitrites so formed are thought by many to be one of the causes of the headache and depression experienced in rooms artificially lighted and poorly ventilated.

The purpose of these experiments was to determine:

(1) Whether reliance could be placed in the common absorption flask methods when the gas to be absorbed was present in such minute quantities.

(2) What was the best absorbent to be used.

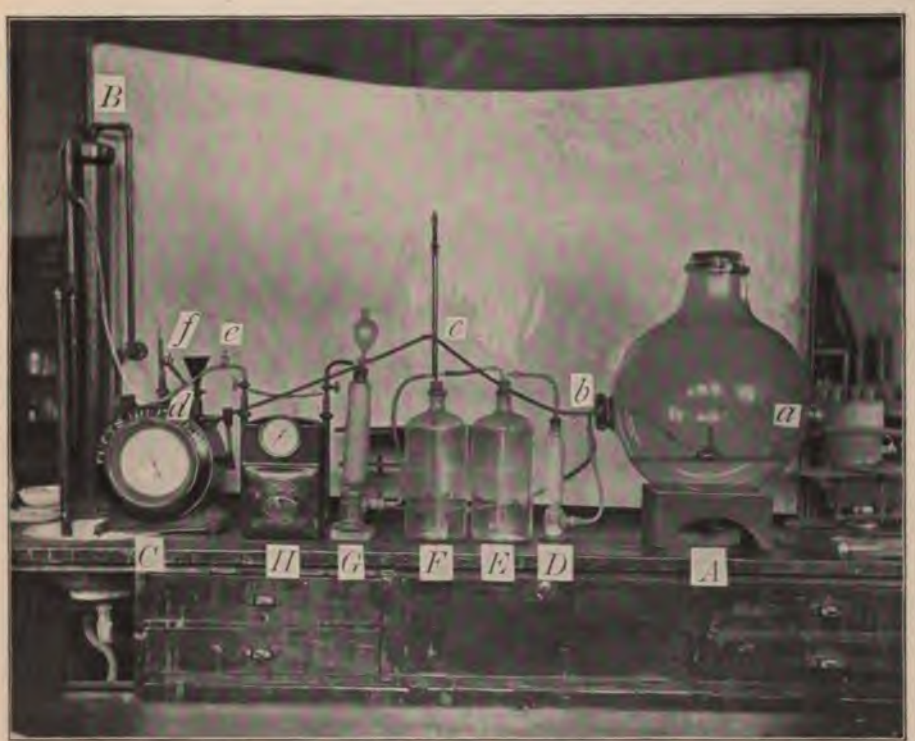
(3) If possible, in what form the gas is present.

(4) What substances, when burned, produce it most abundantly, and whether or not any is formed in the human system.

(5) If possible, what the effect would be of breathing it in considerable quantities.

The apparatus used in these determinations is shown in the accompanying cut.

A is a large 60-liter glass balloon; air enters at *a*, gas enters through one tube at *b*, and the products of combustion are drawn off through another at the same place. *B* is a Richards pump to provide suction. The main current of air passes through the tube *c* to the gas meter *C*, emerging from the latter at *d*. The portion of air to be tested is drawn off from the main current at *b* by means of a T tube, and passes up through the calcium chloride tower *D* which removes the moisture and prevents the excess of nitrites which would occur if condensation took place in the first bottle, *E*. Thence it passes through the two clean, dry, 4-liter bottles *E* and *F*, and up through the absorption flask *G*, filled with glass beads and containing the absorbent to be used. From the flask it passes through the second meter *H*, which registers the volume of air passing through the absorption apparatus, and finally joins the main current again at the T tube *d*, through which it is drawn off. In this way one pump is made to supply suction for both circuits, the amount of air passing through each being regulated by means of the two pinch cocks *e* and *f*. When



Apparatus for Testing the Efficiency of Absorption Tubes.

gas was the fuel, we used the small Bunsen burner shown in the cut, while for kerosene or alcohol we placed little lamps on the shelf shown in the balloon. The calcium chloride tower was found to remove a little of the nitrites along with the moisture, but it was necessary to prevent condensation in the bottles, and moreover the error it introduced was the same in all cases, so that it did not affect the comparative values of the results obtained. After the run, the two bottles were removed, 100 cc. of the absorbent to be used was introduced, and the bottle shaken occasionally and left at least 24 hours, sometimes 48. To secure as complete absorption as possible, the bottles were usually rinsed quickly with ammonia-free water, and the absorption process repeated, though the amounts of nitrites and ammonia so obtained were seldom very considerable. Of the absorbent used, one-half (50 cc.) was employed for the determination of nitrites by the Griess method, while the second half was tested for NH_3 with Nessler's reagent.[1] The standard solutions used for comparison contained, for nitrites .0000001 gram. N per cc.; for NH_3 .00001 gram. NH_3 per cc. When water was used as the absorbent, it was freed from ammonia by redistilling over potassium permanganate. The sodium hydrate used was obtained free from nitrites by dissolving metallic sodium. The strength of the latter usually employed was $\frac{N}{40}$. The air used was taken directly from the laboratory, but the room was not in use for other purposes at the time, and by a special test, in which the number of burners lighted rendered the air worse than it was at the time of any experiment, it was shown that the amounts of nitrites and ammonia obtained from that source were negligible when compared with those obtained in the course of an experiment.

Following is a condensed table of some of the results:

[1] Whenever NaOH was used as the absorbent in the flask, a milkiness resulted on adding the Nessler reagent, making it necessary to distil over the free ammonia before it could be read. The cause of this milkiness was not determined.

No.	Fuel.	Rate of total air passed. (Cu. ft. per hour.)	Calculated from Bottles.		Bottle No. 1.				Bottle No. 2.			
			Total nitrites formed per hour.	Total NH_3 formed per hour.	Absorbent.	Nitrites per cu. m. of air passed.	NH_3 per cu. m. of air passed.	Nitrites per cu. m.: NH_3 per cu. m.	Absorbent.	Nitrites per cu. m. of air passed.	NH_3 per cu. m. of air passed.	Nitrites per cu. m.: NH_3 per cu. m.
1	Gas, non-luminous . . .	24.534	.000917	.00809	H_2O	.00134	.0239	1 : 17.6	....	.....	.....	.....
2	Gas, non-luminous . . .	22.880	.000784	.00676	H_2O	.00123	.0053	1 : 4.3	H_2O	.00253	.0016	1 : 0.6
3	Gas, non-luminous . . .	15.194	.000880	.00024	$Ba(OH)_2$	.00187	....	.....	H_2O	.00208	.0016	1 : 0.5
4	Gas, non-luminous . . .	13.596	.001000	.00204	$NaOH(\frac{N}{18})$	.00264	.0058	1 : 2.0	H_2O	.00240	.0026	1 : 1.1
5	Kerosene	21.234	.001140	.00338	$NaOH(\frac{N}{80})$	.00194	.0058	1 : 2.9	H_2O	.00184	.0042	1 : 2.2
6	Kerosene	20.803	.001110	.00270	$NaOH(\frac{N}{40})$	.00192	.0047	1 : 2.4	H_2O	.00186	.0047	1 : 2.5
*7	Kerosene	20.428	.001330	.00151	NaOH	.00233	.0026	1 : 1.1	H_2O	.00119	.0026	1 : 2.2
*8	Kerosene	19.104	.001180	.00141	NaOH	.00223	.0026	1 : 1.2	H_2O	.00109	.0021	1 : 1.9
9	Alcohol	....	.....	....	Alcohol.	.00074	....	.....	H_2O	.00106	.0074	1 : 7.0
*10	Alcohol	22.550	.001300	.00464	$NaOH(\frac{N}{40})$	.00209	.0074	1 : 3.5	H_2O	.00151	.0079	1 : 5.2
*11	Alcohol	22.810	.001580	.00469	NaOH	.00185	.0074	1 : 4.0	H_2O	.00131	.0079	1 : 5.9
12	Alcohol	18.476	.001170	.00380	NaOH	.00227	.0074	1 : 3.2	H_2O	.00134	.0074	1 : 5.5
13	Gas, luminous	28.586	.001990	.00370	NaOH	.00250	.0047	1 : 1.7	H_2O	.00194	.0063	1 : 3.3
14	Gas, luminous	16.130	.001100	.00119	NaOH	.00247	.0026	1 : 1.0	H_2O	.00212	.0032	1 : 1.4
15	Kerosene	31.492	.001920	.00324	NaOH	.00219	.0037	1 : 1.6	H_2O	.00184	.0032	1 : 1.7

* Tests made at the end of successive half hours.

The results obtained seem to show:

(1) That absorption flask methods are unreliable for determining nitrites when present in the extremely small quantities in which they occur in the air. The amounts obtained from the flask varied widely, and averaged only about one-tenth that obtained from the bottles, one-third being the maximum for the ordinary rate of bubbling at the ordinary temperature. An evaporating dish containing 100 cc. H_2O, and placed in the balloon during the first experiments, collected more nitrites in proportion to the volume of absorbent, than the water used in the absorption flask.

(2) That dilute NaOH is a better absorbent than pure water or alcohol.

(3) That ammonium nitrite is probably not present *as such*. This is indicated by the widely varying ratios of nitrites per cubic meter to NH_3 per cubic meter, which in most of the cases observed is very different from the theoretical ratio 1 : 1.25; and also by the difficulty of absorption. Since ammonium nitrite is a substance readily soluble in water, this difficulty of absorption would seem to indicate either that it is not formed at all in such combustions, or else that if it is formed it at once undergoes dissociation, and N_2O_3 is perhaps changed to some higher oxide of nitrogen which fails to give the Griess reaction. As evidence of the possibility of such oxidation may be mentioned the fact that Berthelot, Stohmann, Rubner and others, found nitrates as well as nitrites in the absorption liquid, though the only two tests made for nitrates in the course of these experiments failed to detect more than a trace. In order to determine if such dissociation was increased by standing, two bottles were allowed to stand 48 hours before introducing the absorbent, but no perceptible difference was found.

(4) That for the same height of flame, kerosene and alcohol give approximately the same amount of nitrites per hour (experiments 8 and 12), while both kerosene and alcohol produce decidedly more than gas when burned under the same conditions (experiments 2, 5, and 11). Gas when burned with a luminous flame seems to produce slightly more than when burned with a non-luminous. In the case of ammonia the results were not so uniform, but apparently the relations are different, gas producing decidedly more than alcohol (experiments 2 and 11), and alcohol slightly more than kerosene (experiments 8 and 12), while a non-luminous gas flame produces more than a luminous

(experiments 1 and 13). As a rule, increasing the supply of air by applying more suction had the effect of increasing the total amounts of both nitrites and ammonia formed in a given time.

The lack of uniformity in these results is probably to be explained by slight variations in the amounts of fuel consumed, for while we endeavored in all cases to have the flames the same height ($1\frac{1}{2}$ inches), slight variations were unavoidable, and no measurement was made of the gas, etc., burned.

The determination of nitrites in the exhaled breath was accomplished by breathing for 1 hour through a 4-liter bottle which contained 100 cc. dilute NaOH, and was shaken constantly. The test was made out of doors, and a small flask was used as a trap for saliva, which reacts quite strongly for nitrites, derived possibly from the exhaled breath. The NaOH when tested showed a considerable quantity of both nitrites and ammonia; a rough calculation of the volume of breath exhaled showing .00028 grams N as nitrite, and .0169 grams NH_3 per cubic meter. A blank test made on the same air by drawing about the same volume through another bottle showed only .000004 grams N as nitrite, and .00006 grams NH_3 per cubic meter, apparently indicating the formation of both substances in the metabolic processes of the body.

(5) In order to test the physiological effects of breathing the nitrites formed in combustion, use was made of a large air-tight box ($7 \times 6\frac{1}{2} \times 4$ feet) which had been employed in previous experiments on carbon dioxide. In this the writer remained 2 hours while the products of combustion from a large Erlenmeyer gas burner placed under an asbestos hood were drawn through. In order to remove as much of the carbon dioxide as possible, the air before entering the box was passed rapidly through an absorption tower containing strong sodium hydrate. This served to remove a large part of the carbon dioxide for the first hour as shown by the following tests made within the box by means of a Fitz apparatus, the first one being made at the beginning of the test:

Time. P. M.	Parts CO_2 per 10000.
1.40	6
2.00	10
2.35	17
3.00	>28

By 3.00 P. M. the NaOH had become exhausted and the CO_2 rose above the amount measurable with the Fitz apparatus.

Fifteen minutes after entering the box a feeling of discomfort was experienced, accompanied by slight perspiration, which at the end of half an hour had increased to decided depression and profuse perspiration. After 45 minutes I felt drowsy and listless, and noticed a slight headache which afterwards disappeared. A smarting of the eyes was felt after an hour and a half, which, together with excessive perspiration, continued till the end. The results of this test were not conclusive, inasmuch as the sodium hydrate took out part of the nitrites, as was shown by the strong reaction obtained from it afterwards, and did not remove all the carbon dioxide. There remained, however, a considerable quantity of nitrites in the air entering the box, as was shown by testing some of the water of condensation which collected on a bottle of ice water placed within, and also by testing a sample of the air drawn out through a bottle. The latter showed .00111 grams N as nitrite per cubic meter. Most of the discomfort experienced seemed to be due to the excessive moisture and high temperature, since on fanning it temporarily disappeared. A subsequent test made with the same burner showed the ratio of nitrites to CO_2 present to be 1 : 2243.

The writer desires to acknowledge his indebtedness to Mrs. E. H. Richards, at whose suggestion and under whose supervision the above experiments were made, and to Dr. C. A. Meserve and Mr. A. G. Woodman for much kind assistance.

RESULTS OF TESTS MADE IN THE ENGINEERING LABORATORIES.

XI.

APPLIED MECHANICS.

ALUMINUM TESTS.

THE specimens tested were sent by the Pittsburgh Reduction Company. No chemical analysis of the specimens was made, but they are presumably nearly pure aluminum.

TENSION TESTS ON ALUMINUM WIRE.

Number of test.	Date, 1898–99.	Diameter of cross section. (Ins.)	Area of cross section. (Sq. ins.)	Gauged length. (Ins.)	Limits of loads used for calculation of modulus of elasticity. (Lbs.)	Elastic elongation for difference of loads used in calculation of modulus of elasticity. (Ins.)	Modulus of elasticity. (Lbs. per sq. in.)
1	Oct. 25	0.1281	0.0129	50.0	20 — 120	0.0403	9,630,000
2	Oct 31	0.1278	0.0128	50.0	70 — 160	0.0396	8,860,000
3	Nov. 1	0.1279	0.0129	50.0	125 — 200	0.0300	9,730,000
4	Nov. 3	0.1281	0.0129	50.0	25 — 125	0.0438	8,860,000
5	Nov. 8	0.1281	0.0129	50.0	25 — 125	0.0412	9,420,000
6	Nov. 10	0.1280	0.0129	50.0	25 — 125	0.0406	9,570,000
7	Nov. 14	0.1282	0.0129	50.0	25 — 125	0.0441	8,800,000
8	Nov. 21	0.1278	0.0128	50.0	50 — 150	0.0369	10,600,000
9	Dec. 1	0.1280	0.0129	50.0	25 — 125	0.0362	10,700,000
10	Dec. 6	0.1281	0.0129	50.0	25 — 125	0.0363	10,700,000
11	Dec. 7	0.1283	0.0129	50.0	75 — 195	0.0496	9,360,000
12	Dec. 12	0.1282	0.0129	50.0	25 — 125	0.0394	9,830,000
13	Dec. 13	0.1281	0.0129	50.0	25 — 125	0.0368	10,600,000
14	Dec. 14	0.1280	0.0129	50.0	50 — 175	0.0496	9,790,000

TENSION TESTS ON ALUMINUM WIRE. — *Concluded.*

Number of test.	Date, 1898–99.	Elastic limit. (Lbs.)	Elastic limit. (Lbs. per sq. in.)	Maximum load. (Lbs.)	Maximum load. (Lbs. per sq. in.)	Area of fractured section. (Sq. in.)	Reduction of area. (Per cent.)	Ultimate extension in 48 inches.	Ultimate extension. (Per cent.)
1	Oct. 25	200	15,500	343	26,600	0.00229	82.2	0.31	0.65
2	Oct. 31	160	12,500	337	26,300	0.00212	83.4	....	....
3	Nov. 1	240	18,700	345	26,900	0.00251	80.5	0.31	0.65
4	Nov. 3	225	17,500	336	26,100	0.00246	80.9	....	....
5	Nov. 8	195	15,100	340	26,400	0.00264	79.5	0.26	0.52
6	Nov. 10	225	17,500	338	26,300	0.00274	78.7	....	....
7	Nov. 14	225	17,400	336	26,000	0.00302	76.6	0.15	0.30
8	Nov. 21	245	19,100	331	25,800	0.00174	86.5	....	....
9	Dec. 1	225	17,500	346	26,900	0.00181	85.9	....	....
10	Dec. 6	225	17,500	338	26,200	0.00322	75.0	0.31	0.62
11	Dec. 7	225	17,400	336	25,900	0.00221	82.9	0.27	0.54
12	Dec. 12	235	18,200	347	26,900	0.00270	79.1	0.51	1.02
13	Dec. 13	225	17,500	347	26,900	0.00255	80.2	....	....
14	Dec. 14	225	17,500	346	26,900	0.00258	80.0	0.46	0.92

TORSION TEST ON ALUMINUM ROD. (SERIES 1.)

Number of test.	Date, 1898.	Diameter of specimen. (Ins.)	Length between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws.	Apparent outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Oct. 26	0.2572	12.0	57.0	40.4	17,100	3.37
2	Oct. 26	0.2567	12.0	53.0	25.0	15,900	2.08
3	Oct. 29	0.2571	12.0	59.2	32.8	17,700	2.73
4	Oct. 29	0.2559	12.0	60.4	35.7	18,300	2.98
5	Nov. 2	0.2568	12.0	68.1	43.8	17,500	3.65
6	Nov. 4	0.2571	12.0	58.0	18.9	17,400	1.58
7	Nov. 4	0.2576	12.0	58.8	23.8	17,500	1.98
8	Nov. 7	0.2564	12.0	58.8	47.3	17,800	3.94
9	Nov. 9	0.2557	12.0	56.0	27.9	17,000	2.33
10	Nov. 11	0.2566	12.0	58.2	40.7	17,600	3.39

TORSION TESTS ON ALUMINUM ROD. (SERIES 2.)

Number of test.	Date, 1898.	Diameter of specimen. (Ins.)	Length between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws.	Apparent outside fiber stress. (Lbs. per sq. in.)	Average number of turns between jaws, per inch.
1	Nov. 2	0.3668	12.0	179.5	24.1	18,500	2.01
2	Nov. 7	0.3665	12.0	185.4	23.9	19,200	1.99
3	Nov. 9	0.3669	12.0	181.7	25.8	18,700	2.15
4	Nov. 11	0.3674	12.0	180.9	24.4	18,600	2.03
5	Nov. 14	0.3668	12.0	177.9	31.7	18,400	2.64
6	Nov. 16	0.3669	12.0	178.2	26.8	18,400	2.23
7	Nov. 21	0.3668	12.0	180.0	23.5	18,600	1.96
8	Nov. 23	0.3666	12.0	184.0	14.4	19,000	1.20
9	Nov. 28	0.3669	12.3	181.2	26.4	18,700	2.17
10	Dec. 1	0.3669	12.0	182.4	23.9	18,800	1.94

TORSION TESTS ON ALUMINUM ROD. (SERIES 3.)

Number of test.	Date, 1898.	Diameter of specimen. (Ins.)	Distance between jaws.	Maximum twisting moment. (In. lbs.)	Number of turns between jaws.	Apparent outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Nov. 14	0.4590	12.0	398.7	12.2	21,000	1.02
2	Nov. 16	0.4590	12.0	395.2	12.3	20,800	1.03
3	Nov. 21	0.4588	12.0	398.6	11.5	21,000	0.96
4	Nov. 23	0.4589	12.0	400.4	10.5	21,100	0.87
5	Nov. 28	0.4589	12.1	405.0	11.9	21,300	0.99
6	Dec. 1	0.4588	12.0	399.3	12.7	21,100	1.06
7	Dec. 5	0.4586	12.0	399.2	12.2	21,100	1.02
8	Dec. 5	0.4587	12.1	402.7	11.5	21,200	0.95
9	Dec. 9	0.4588	12.0	395.3	11.7	20,800	0.97
10	Dec. 12	0.4590	12.0	393.1	11.9	20,700	0.99
11	Dec. 14	0.4588	12.0	407.6	12.2	21,500	1.02

TORSION TESTS ON ALUMINUM TUBE. (SERIES 1.)

Number of test.	Date, 1899.	External diameter of specimen. (Ins.)	Internal diameter of specimen. (Ins.)	Length of specimen between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws.	Apparent outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Jan. 2	0.2513	0.1470	12.0	53.6	14.22	19,500	1.19
2	Jan. 2	0.2519	0.1484	12.0	50.6	17.5	18,300	1.46
3	Jan. 6	0.2515	0.1529	12.0	52.0	17.1	19,300	1.43
4	Mar. 30	0.2571	0.1473	10.0	58.0	4.2	19,500	0.42
5	Mar. 30	0.2515	0.1473	12.0	48.6	17.6	17,600	1.47
6	Mar. 30	0.2515	0.1473	13.0	48.2	6.2	17,500	0.52
7	Mar. 31	0.2550	0.1500	12.0	54.0	17.6	19,600	1.47
8	Mar. 31	0.2513	0.1500	12.0	51.0	15.7	18,700	1.31

TORSION TESTS ON ALUMINUM TUBE. (SERIES 2.)

Number of test.	Date, 1898–9.	External diameter. (Ins.)	Internal diameter. (Ins.)	Distance between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws.	Apparent outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Dec. 14	0.3750	0.2772	12.0	97.5	8.65	13,400	0.72
2	Dec. 16	0.3749	0.2754	13.0	84.9	7.15	11,600	0.55
2	Dec. 19	0.3756	0.2772	12.0	97.3	7.2	13,300	0.60
4	Dec. 23	0.3749	0.2775	12.0	85.1	2.7	11,800	0.23
5	Dec. 30	0.3735	0.2776	12.0	74.0	0.70	10,100	0.06
6	Jan. 2	0.3743	0.2755	12.0	73.9	4.00	10,300	0.33
7	Jan. 2	0.3739	0.2769	12.0	77.2	2.29	10,800	0.19
8	Jan. 6	0.3751	0.2788	12.0	85.0	8.0	11,800	0.67
9	Jan. 11	0.3753	0.2983	12.0	76.0	3.4	12,200	0.28
10	Jan. 11	0.3750	0.2772	13.0	93.8	6.3	12,900	0.53

TORSION TESTS ON ALUMINUM TUBE. (SERIES 3.)

Number of test.	Date, 1898–9.	External diameter of specimen. (Ins.)	Internal diameter of specimen. (Ins.)	Length between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws.	Apparent outside fiber stress. (Lbs. per sq. in.)	Average number of turns between jaws.
1	Dec. 16	0.5007	0.3688	13.5	341.0	9.5	19,500	0.70
2	Dec. 19	0.5007	0.3623	12.0	329.6	4.45	18,400	0.37
3	Dec. 23	0.5019	0.3634	12.0	371.0	7.05	20,600	0.59
4	Dec. 30	0.5002	0.3631	12.0	340.0	6.8	19,200	0.57
5	Jan. 11	0.5011	0.3661	12.0	365.7	7.0	20,700	0.53
6	Jan. 11	0.5009	0.3645	12.0	352.0	6.0	20,000	0.50
7	Mar. 2	0.5011	0.3635	12.0	323.7	9.8	18,100	0.82
8	Mar. 2	0.5009	0.3625	10.0	366.1	1.83	20,600	0.18
9	Mar. 2	0.5012	0.3638	12.0	348.3	9.3	19,500	0.78
10	Mar. 4	0.5007	0.3632	12.0	330.5	9.9	18,500	0.83

PHOSPHOR BRONZE.

TORSION TESTS UPON PHOSPHOR BRONZE ROD.

Date, 1899.	Diameter of cross section. (Ins.)	Length of specimen between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws.	Apparent outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
Mar. 6	0.2506	9.6	254.9	10.28	82,500	1.08
Mar. 6	0.2507	7.9	254.4	9.7	82,100	1.22
Mar. 7	0.2509	7.0	263.5	9.59	84,900	1.37
Mar. 7	0.2503	8.0	256.0	9.54	83,100	1.19
Mar. 11	0.2505	8.0	256.0	10.77	82,900	1.35
Mar. 11	0.2505	8.0	261.3	10.73	84,700	1.34
Mar. 11	0.2505	8.0	242.9	8.2	78,600	1.03
Mar. 13	0.2504	8.0	255.0	....	82,700	....
Mar. 13	0.2505	8.0	264.0	10.5	85,500	1.29
Mar. 14	0.2508	8.0	261.0	7.46	84,300	0.93
Mar. 14	0.2510	8.0	269.0	12.0	86,700	1.50
Mar. 16	0.2506	8.0	258.5	6.1	83,700	0.76
Mar. 16	0.2506	8.0	254.4	8.1	82,400	1.01
Mar. 21	0.2507	8.0	251.0	8.6	81,000	1.08
Mar. 23	0.2509	8.0	252.0	11.9	81,200	1.49
Mar. 23	0.2507	8.0	240.0	7.4	77,500	0.93
Mar. 25	0.2506	13.0	247.0	17.0	80,000	1.31
Mar. 25	0.2510	8.0	250.2	9.82	80,600	1.23
Mar. 28	0.2504	8.0	248.7	....	80,700	....
Mar. 28	0.2508	8.0	249.3	9.1	80,500	1.14

NOTE. — These tests were made upon ordinary phosphor bronze round rod. The surface was nicely finished. The diameter at different portions of the rod did not vary more than 0.001 inch.

TORSION TESTS ON COLD ROLLED STEEL SHAFTING $1\frac{11}{16}''$ DIAMETER. (From Jones & Laughlin's.)

Number of test.	Date, 1898–9.	Diameter of cross section. (Ins.)	Distance between jaws. (Ins.)	Gauged length. (Ins.)	Elastic limit. (In. lbs.)	Outside fiber stress at elastic limit. (Lbs. per sq. in.)	Maximum twisting moment. (In. lbs.)	Apparent outside fiber stress as calculated from maximum twisting moment. (Lbs. per sq. in.)	Limits of loads for calculating shearing modulus of elasticity. (In. lbs.)	Angle of twist for difference of loads used in calculating shearing modulus of elasticity.	Shearing modulus of elasticity. (Lbs. per sq. in.)	Number of turns between jaws at fracture.	Turns per foot between jaws at fracture.
										° ′ ″			
1	Dec. 17	1.684	71.8	48.0	36,400	38,800	77,760	82,900	1800 — 7200	1 34 30	11,900,000	11.00	1.84
2	Dec. 17	1.686	71.8	48.0	34,200	36,400	68,490	72,800	3600 — 9000	1 35 10	11,800,000	10.71	1.79
3	Mar. 2	1.686	71.0	48.0	30,870	32,800	67,230	71,500	1800 — 7200	1 34 10	12,000,000	12.21	2.06
4	Mar. 7	1.686	71.2	48.0	34,200	36,400	70,560	75,000	1800 — 7200	1 33 20	12,000,000	9.97	1.58
5	Mar. 8	1.686	71.0	48.0	34,200	36,400	71,190	75,700	1800 — 7200	1 33 30	12,000,000	9.48	1.60
6	Mar. 9	1.686	71.0	48.0	30,600	32,500	66,510	70,700	1800 — 7200	1 34 00	12,000,000	11.65	1.97
7	Mar. 14	1.686	71.4	48.0	32,400	34,400	68,850	73,200	1800 — 7200	1 32 30	12,000,000	11.30	1.90
8	Mar. 16	1.687	71.2	45.8	32,400	34,400	68,670	72,800	1800 — 7200	1 30 50	11,800,000	11.26	1.90
9	Mar. 18	1.686	71.1	48.0	32,400	34,400	68,850	73,200	1800 — 7200	1 34 20	11,900,000	10.74	1.81
10	Mar. 20	1.687	71.1	48.0	32,400	34,300	71,100	75,300	1800 — 7200	1 33 30	12,000,000	10.49	1.77
11	Mar. 25	1.685	71.2	48.0	30,600	32,500	69,060	73,400	1800 — 7200	1 33 00	12,100,000	10.15	1.71
12	Apr. 1	1.684	71.4	48.0	30,600	32,600	66,370	70,800	1800 — 7200	1 35 40	11,800,000	10.42	1.75

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Rope Tests.

TESTS UPON COTTON ROPE $\frac{7}{8}''$ DIAMETER.

The tests upon rope the past year have been made with several objects in view. It was desired to obtain the relative holding power of various kinds of knots, the relative efficiency of various knots for uniting two ends of a rope, the stretch of a rope under a gradually increasing load, and the maximum tensile strength of the rope in question. A grade of white cotton rope $\frac{7}{8}$ of an inch in diameter was selected for a series of tests. The two coils used contained about 700 feet in all. The series of knots tested for holding power is illustrated in a former report of rope tests. (See page 392, Vol. X, No. 4, *Technology Quarterly.*) The knots used in tying the ends of the rope together are illustrated by Figures 1–5.

The apparatus used for measuring the stretch of the rope was adjusted at an initial load of 20 pounds, and readings of stretch taken as the load was gradually increased. As the stretch depends to a certain extent on the time the specimen is under load, records of the time required to reach the maximum load were kept. The breaking load was reached in the case of the cotton rope in about 20 minutes; in the case of the manila rope in about 10 minutes.

Considerable difficulty was experienced in fastening the ends of the cotton rope to the testing machine in such a way as to get the break to come in the central part of the specimen. Eye splices which serve for manila, hemp and sisal would not answer in the case of cotton rope. A number of methods of holding were tried with poor success, the rope invariably breaking at the knot at one of the holders. The timber hitch has been found by previous tests on other kinds of rope to give an efficiency of about 76 per cent.

For purposes of comparison it was assumed that cotton rope fastened in this way to the testing machine gave at failure 76 per cent. of the true strength, which would appear to be about 4,420 pounds. Upon this basis the efficiencies given in the table were calculated.

MANILA ROPE TESTS.

The following tests were made in much the same manner upon manila rope. The rope was 2 inches in circumference and was taken from one large coil. The maximum strength was obtained without difficulty from the specimens held at the ends by eye splices. Tests were made also on 6″ manila rope.

FIG. 1. — SQUARE KNOT.

FIG. 2. — OPEN HAND KNOT.

FIG. 3. — WEAVER'S KNOT.

FIG. 4. — ENGLISHMAN'S TIE.

FIG. 5. — ORDINARY TIE.

COTTON ROPE TESTS.

Number of test.	Date, 1898–9.	Number of feet per pound.	Number of turns of one strand per foot.	Maximum load. (Lbs.)	Average strength. (Lbs.)	Efficiency of knot. (Per cent.)	Method of Holding.
1	Oct. 26	6.67	6	3,470	3,360	76	Timber hitch knots at both ends, tied over 2-inch pipe couplings.
2	Nov. 7	4.91	6	2,960			
3	Dec. 5	6.00	6	3,920			
4	Dec. 14	6.00	6	3,620			
5	Dec. 14	5.52	6	3,190			
6	Mar. 4	5.11	5½	3,020			
7	Dec. 1	7.25	6	3,890	3,430	78	Slip knots at both ends, tied over 2-inch pipe couplings.
8	Nov. 2	6.52	6	2,820			
9	Nov. 9	6.95	6	3,090			
10	Dec. 14	5.52	6	3,740			
11	Jan. 4	5.77	..	3,620			
12	Nov. 4	....	6	2,550	3,380	76	Double half hitch knots at both ends, tied over 2-inch pipe couplings.
13	Nov. 7	5.00	6	3,100			
14	Dec. 1	7.25	6	3,920			
15	Dec. 12	6.13	6	3,440			
16	Dec. 30	6.75	6	3,870			
17	Nov. 21	4.76	6	2,570	2,680	61	Bowline knots, tied over iron eyes.
18	Oct. 24	4.56	5⅝	2,970			
19	Oct. 26	6.13	6	2,400			
20	Dec. 9	5.72	6	2,580			
21	Dec. 19	....	6	2,880			
22	Oct. 24	4.69	5⅝	2,140	2,170	49	Flemish loop knots, tied over iron eyes.
23	Nov. 4	4.70	6	2,210			
24	Nov. 21	4.70	6	2,090			
25	Dec. 12	5.50	6	2,120			
26	Dec. 21	5.52	6	2,270			
27	Nov. 14	6.29	..	2,520	2,410	55	Englishman's tie at center of rope. Ends tied in timber hitch knots over 2-inch pipe couplings.
28	Nov. 21	4.89	6	2,280			
29	Dec. 9	5.50	6	2,460			
30	Jan. 2	6.75	..	2,370			
31	Nov. 10	6.38	5½	2,380	2,330	53	Square knot at center of rope. Ends tied in timber hitch knots over 2-inch pipe couplings.
32	Nov. 16	4.89	5⅝	2,200			
33	Dec. 5	...	6	2,470			
34	Dec. 12	5.50	6	2,270			
35	Nov. 10	6.00	5½	2,120	2,090	47	Weaver's knot at center of rope. Ends tied in timber hitch knots over 2-inch pipe couplings.
36	Nov. 16	4.89	5⅝	1,700			
37	Dec. 19	5.50	6	2,460			
38	Dec. 21	5.50	6	2,090			
39	Nov. 14	6.29	5⅝	1,930	2,110	48	Open hand knot at center of rope. Ends tied in timber hitch knots over 2-inch pipe couplings.
40	Nov. 21	4.68	6	2,150			
41	Dec. 12	5.50	6	2,240			

Note. — The cotton rope was ⅝ of an inch in diameter. All specimens in the knot tests were tested in a dry condition. The length of the specimen between holdings was about 4 feet. In the tests upon holding power the specimens all broke at one of the end knots. In the tests upon center knots the specimens all broke in the twists of the center knots.

TENSION TESTS ON 2″ MANILA ROPE. (3 strands.)

Number of test.	Date.	Number of feet per pound.	Number of turns of one strand per foot.	Condition.	Location of break.	Maximum load.	Average strength. (Lbs.)	Efficiency of knot or splice. (Per cent.)	Kind of knots or splices used.
1	Apr. 7, 1898	7.4	5½	Splices wet. Center of rope dry.	At center.	4,500	4,760	100	Eye splices at ends over iron eyes.
2	Apr. 12, 1898	...	6		At center.	4,800			
3	Apr. 14, 1898	7.8	6		At center.	4,910			
4	Apr. 23, 1898	...	..		At center.	4,810			
5	Dec. 3, 1897	7.4	6	Dry.	Upper knot.	3,290	3,140	66	Timber hitches at ends over 2″ pipe couplings.
6	Dec. 4, 1897	7.4	5½		Lower knot.	3,090			
7	Dec. 20, 1897	...	6		Lower knot.	3,040			
8	Dec. 9, 1897	7.1	6	Dry.	Lower knot.	2,890	2,840	60	Bowlines at ends over iron eyes.
9	Dec. 21, 1897	8.0	6		Upper knot.	2,670			
10	Jan. 1, 1898	7.3	6		Upper knot.	2,490			
11	Mar. 31, 1898	7.8	6		Lower knot.	2,720			
12	Mar. 31, 1898	...	6		Upper knot.	3,140			
13	Apr. 6, 1898	...	..		Lower knot.	3,140			
14	Dec. 21, 1897	7.7	6	Dry.	Upper knot.	1,930	2,090	44	Flemish loops at ends over iron eyes.
15	Jan. 1, 1898	7.0	6		Upper knot.	1,910			
16	Mar. 29, 1898	...	6½		Lower knot.	2,160			
16a	Mar. 29, 1898	7.5	5½		Lower knot.	2,340			
17	Oct. 13, 1897	...	6	Dry.	Middle knot.	3,540	2,910	61	Joined at middle with Englishman's knot. Held at ends with timber hitches.
18	Oct. 15, 1897	7.4	5½		Middle knot.	3,160			
19	Oct. 20, 1897	7.2	6		Middle knot.	2,750			
20	Oct. 29, 1897	...	6		Middle knot.	3,290			
21	Nov. 3, 1897	...	6½		Middle knot.	2,250			
22	Nov. 5, 1897	...	6		Middle knot.	2,680			
23	Dec. 9, 1897	7.1	6½		Middle knot.	2,730			
24	Dec. 8, 1897	7.0	6	Dry.	Middle knot.	2,910	2,700	57	Joined at middle with ordinary tie. Held at ends with timber hitches.
25	Dec. 8, 1897	7.0	6		Middle knot.	2,860			
26	Dec. 8, 1897	7.0	6		Middle knot.	2,780			
27	Dec. 8, 1897	7.5	6		Middle knot.	2,540			
28	Dec. 9, 1897	7.5	6		Middle knot.	2,410			
29	Oct. 13, 1897	7.0	6	Dry.	Middle knot.	2,530	2,480	52	Joined at middle with square knot. Held at ends with timber hitches.
30	Oct. 18, 1897	7.4	6		Middle knot.	2,300			
31	Oct. 27, 1897	7.3	6		Middle knot.	2,670			
32	Oct. 29, 1897	...	6		Middle knot.	2,450			
33	Nov. 5, 1897	...	6		Middle knot.	2,680			
34	Nov. 9, 1897	...	6		Middle knot.	2,220			
35	Oct. 11, 1897	...	6	Dry.	Middle knot.	2,370	2,180	46	Joined at middle with open hand knot. Held at ends with timber hitches.
36	Oct. 3, 1897	7.0	6		Middle knot.	2,310			
37	Oct. 27, 1897	7.3	6		Middle knot.	2,200			
38	Nov. 3, 1897	...	6½		Middle knot.	2,020			
39	Nov. 9, 1897	...	6		Middle knot.	2,000			

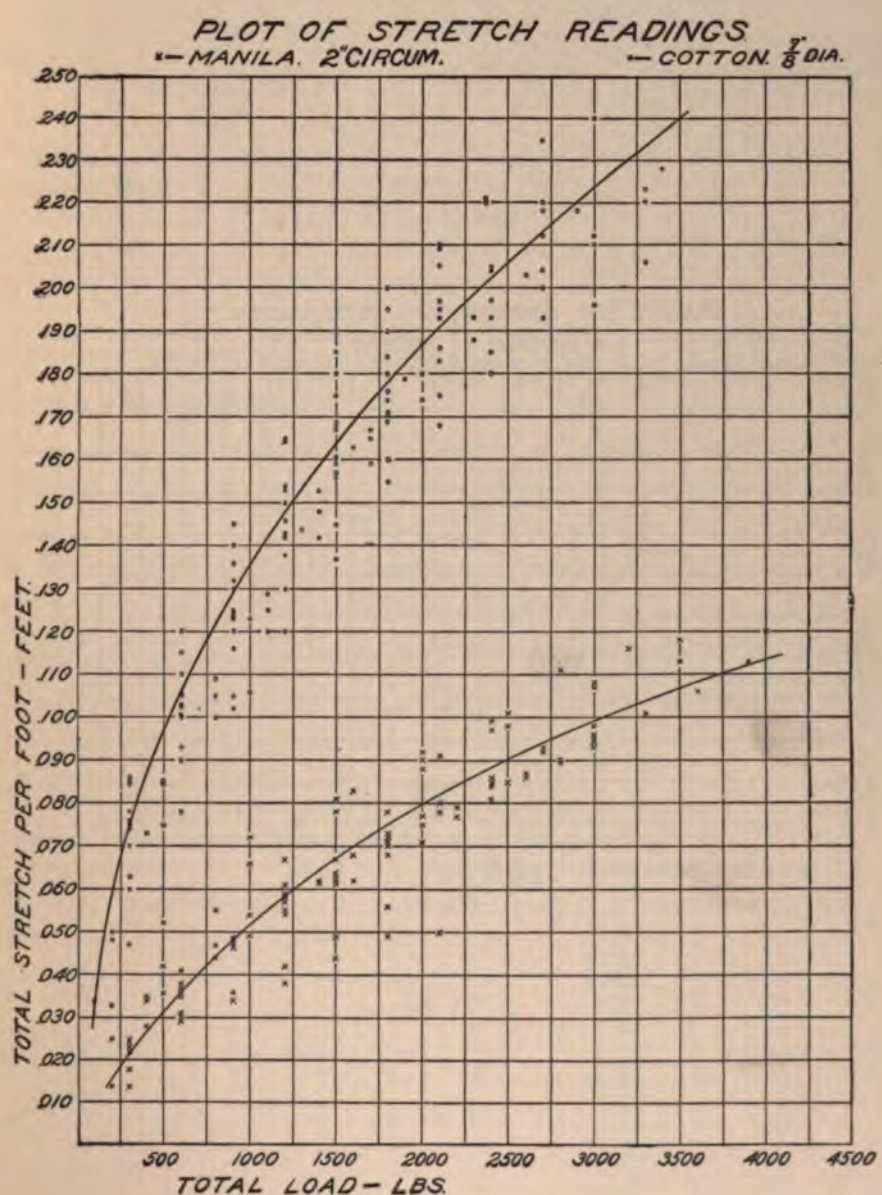

PLOT OF STRETCH READINGS
×— MANILA. 2" CIRCUM.
—COTTON. 7/8" DIA.
TOTAL STRETCH PER FOOT — FEET.
.250
.240
.230
.220
.210
.200
.190
.180
.170
.160
.150
.140
.130
.120
.110
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
500
1000
1500
2000
2500
3000
3500
4000
4500
TOTAL LOAD — LBS.

FIG. 6.

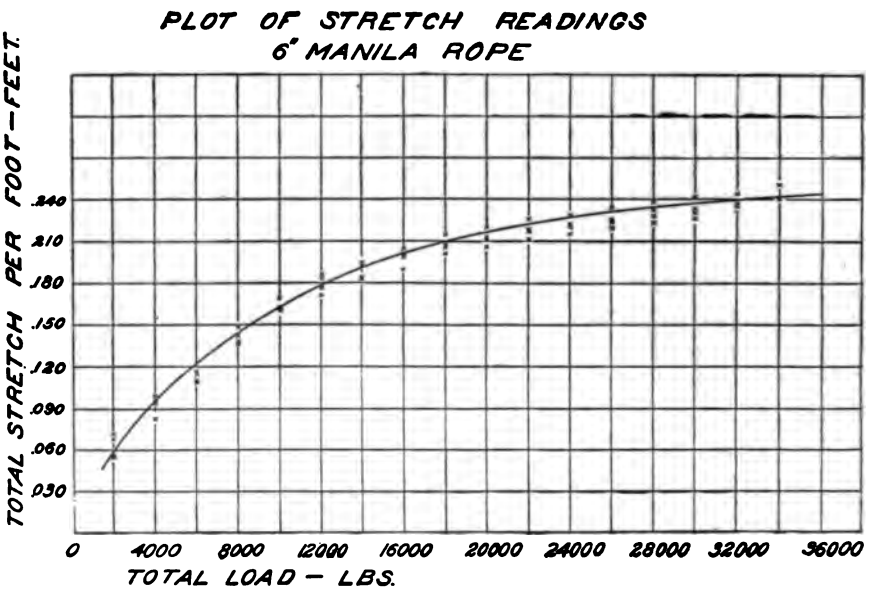

PLOT OF STRETCH READINGS
6" MANILA ROPE
TOTAL STRETCH PER FOOT—FEET.
.240
.210
.180
.150
.120
.090
.060
.030
0
4000
8000
12000
16000
20000
24000
28000
32000
36000
TOTAL LOAD — LBS.

FIG. 7.

TESTS ON MANILA ROPE. (6″ circumference.)

Number of test.	Date.	Maximum Load.	Location of Break.	Kind of Knots or Splices used.
1	Nov. 4, 1898 . .	35,700	Scale end splice.	Eye splices over iron eyes.
2	Nov. 4, 1898 . .	33,100	Power end splice.	
3	Nov. 4, 1898 . .	34,800	3″ from scale end splice.	
4	Nov. 4, 1898 . .	33,400	Scale end splice.	

These tests were made in the Emery Testing Machine. The splices were wet, and the central portion of the rope dry. The following is a plot of the scale readings upon the stretch apparatus for ordinates and loads for abscissæ. The rope consisted of 4 strands of 51 lines per strand, twisted over a core made up of 3 strands, 7 lines per strand, making a total of 225 lines.

Cement Tests.

The tests on cement in tension were made on briquettes of 1 square inch cross section, and in compression on 2″ cubes. A description of the method of making these tests may be found in the *Technology Quarterly*, Vol. IX, Nos. 2, 3, 1896. The sand used in making the sand tests was ground white quartz fine enough to pass through a sieve with 20 meshes per linear inch.

PORTLAND CEMENT. — NEAT CEMENT. (Tension.)

Date of Test.	Brand.	Per cent. of Water Used in Mixing.	Time of Set.	Breaking Strength.
Nov. 20, 1897	Atlas.	20	2 days.	434
Nov. 20, 1897	"	20	2 days.	420
Nov. 5, 1897	"	20	4 days.	666
Nov. 5, 1897	"	20	4 days.	720
Nov. 5, 1897	"	20	4 days.	746
Nov. 3, 1897	"	20	5 days.	686
Nov. 3, 1897	"	20	5 days.	728
Oct. 18, 1897	"	23	7 days.	724
Oct. 20, 1897	"	23	7 days.	708
Oct. 20, 1897	"	23	7 days.	715
Oct. 22, 1897	"	20	7 days.	708
Oct. 22, 1897	"	20	7 days.	718
Oct. 22, 1897	"	20	7 days.	740
Oct. 22, 1897	"	20	7 days.	818
Oct. 25, 1897	"	20	7 days.	700
Nov. 3, 1897	"	20	7 days.	750
Nov. 3, 1897	"	20	7 days.	784
Nov. 3, 1897	"	20	7 days.	816
Nov. 19, 1897	"	20	7 days.	724
Nov. 19, 1897	"	20	7 days.	838
Nov. 22, 1897	"	20	7 days.	795
Nov. 22, 1897	"	20	7 days.	832

PORTLAND CEMENT. — NEAT CEMENT. (Tension.) — *Concluded.*

Date of Test.	Brand.	Per cent. of Water Used in Mixing.	Time of Set.	Breaking Strength.
Nov. 24, 1897	Atlas.	20	7 days.	749
Nov. 24, 1897	"	20	7 days.	780
Nov. 24, 1897	"	20	7 days.	845
Dec. 9, 1897	"	20	7 days.	786
Dec. 11, 1897	"	20	7 days.	786
Nov. 10, 1897	"	20	9 days.	802
Nov. 10, 1897	"	20	9 days.	812
Nov. 10, 1897	"	20	9 days.	790
Dec. 10, 1897	"	20	9 days.	910
Nov 8, 1897	"	19.5	12 days.	900
Nov. 8, 1897	"	19.5	12 days.	916
Nov. 8, 1897	"	19.5	12 days.	960
Nov. 8, 1897	"	19.5	12 days.	964
Nov. 8, 1897	"	19.5	12 days.	965
Dec. 31, 1898	Alsen.	27	1 day.	290
Dec. 31, 1898	"	27	1 day.	290
Dec. 31, 1898	"	27	1 day.	296
Dec. 31, 1898	"	27	1 day.	330
Dec. 31, 1898	"	27	1 day.	336
Dec. 31, 1898	"	27	1 day.	348
Dec. 31, 1898	"	27	1 day.	348
Nov. 11, 1898	"	27	2 days.	530
Nov. 11, 1898	"	27	2 days.	556
Nov. 11, 1898	"	27	2 days.	514
Dec. 16, 1898	"	27	2 days.	509
Dec. 16, 1898	"	27	2 days.	520
Dec. 16, 1898	"	27	2 days.	640
Jan. 6, 1899	"	27	2 days.	545
Jan. 11, 1899	"	27	2 days.	520
Dec. 21, 1898	"	27	5 days.	544
Dec. 21, 1898	"	27	5 days.	580
Dec. 21, 1898	"	27	5 days.	580
Dec. 21, 1898	"	27	5 days.	610
Dec. 21, 1898	"	27	5 days.	652
Dec. 21, 1898	"	27	5 days.	668
Nov. 14, 1898	"	27	7 days.	678
Nov. 14, 1898	"	27	7 days.	690
Nov. 14, 1898	"	27	7 days.	780
Jan. 9, 1899	"	27	7 days.	770
Jan. 9, 1899	"	27	7 days.	790
Jan. 9, 1899	"	27	7 days.	790
Nov. 16, 1898	"	27	14 days.	770
Nov. 16, 1898	"	27	14 days.	780
Nov. 16, 1898	"	27	14 days.	844
Dec. 12, 1898	"	27	14 days.	832
Jan. 11, 1899	"	27	1 mo.	836
Jan. 11, 1899	"	27	1 mo.	914
Mar. 16, 1899	Saylor's.	24	2 days.	426
Mar. 16, 1899	"	24	2 days.	440
Mar. 16, 1899	"	24	2 days.	498
Mar. 16, 1899	"	24	2 days.	498
Mar. 16, 1899	"	24	7 days.	722
Dec. 20, 1898	"	24	7 days.	700
Dec. 20, 1898	"	24	7 days.	720
Dec. 20, 1898	"	24	7 days.	820
Dec. 20, 1898	"	24	7 days.	838
Dec. 20, 1898	"	24	7 days.	870
Mar. 13, 1899	"	24	7 days.	702
Mar. 13, 1899	"	24	7 days.	724
Mar. 13, 1899	"	24	7 days.	752
Mar. 14, 1899	"	24	7 days.	706
Mar. 14, 1899	"	24	7 days.	824
June 12, 1899	"	24	3 mos.	975
June 12, 1899	"	24	3 mos.	1,065
June 12, 1899	"	24	3 mos.	1,000
June 12, 1899	"	24	3 mos.	1,085
June 12 1899	"	24	3 mos.	1,050
June 12, 1899	"	24	3 mos.	930

PORTLAND CEMENT.—NEAT CEMENT. (Compression.)

Date of Test.	Brand.	Per cent. of Water Used in Mixing.	Time of Set.	Breaking Strength.
Nov. 20, 1897	Atlas.	20	2 days.	11,950
Nov. 20, 1897	"	20	2 days.	12,910
Nov. 20, 1897	"	20	2 days.	13,750
Nov. 5, 1897	"	20	4 days.	19,740
Nov. 5, 1897	"	20	4 days.	20,180
Nov. 5, 1897	"	20	4 days.	20,830
Nov. 5, 1897	"	20	4 days.	22,000
Nov. 3, 1897	"	20	5 days.	20,000
Nov. 3, 1897	"	20	5 days.	21,030
Nov. 3, 1897	"	20	5 days.	21,150
Nov. 3, 1897	"	20	5 days.	21,160
Nov. 24, 1897	"	20	6 days.	22,550
Oct. 22, 1897	"	20	7 days.	22,990
Oct. 22, 1897	"	20	7 days.	23,670
Oct. 22, 1897	"	20	7 days.	24,000
Oct. 22, 1897	"	20	7 days.	24,000
Oct. 22, 1897	"	20	7 days.	25,000
Oct. 22, 1897	"	20	7 days.	25,140
Oct. 22, 1897	"	20	7 days.	23,120
Nov. 10, 1897	"	20	9 days.	24,820
Nov. 10, 1897	"	20	9 days.	24,850
Nov. 10, 1897	"	20	9 days.	26,000
Dec. 10, 1897	"	20	9 days.	25,450
Dec. 10, 1897	"	20	9 days.	25,800
Nov 10, 1897	"	20	1 mo.	30,600
Nov. 10, 1897	"	20	1 mo.	30,700
Nov. 24, 1897	"	20	1 mo.	34,000
Nov. 24, 1897	"	20	1 mo.	36,000
Oct. 29, 1898	"	20	1 year.	59,400
Oct. 29, 1898	"	20	1 year.	53,550
Oct. 29, 1898	"	20	1 year.	59,400
Oct. 29, 1898	"	20	1 year.	62,150
Oct. 29, 1898	"	20	1 year.	63,900
Oct. 29, 1898	"	20	1 year.	67,050
Oct. 29, 1898	"	20	1 year.	67,550
Dec. 31, 1898	Alsen.	20	1 day.	7,100
Dec. 31, 1898	"	20	1 day.	7,840
Dec. 31, 1898	"	20	1 day.	7,880
Dec. 31, 1898	"	20	1 day.	8,180
Dec. 31, 1898	"	27	1 day.	8,400
Dec. 31, 1898	"	27	1 day.	8,900
Nov. 11, 1898	"	27	2 days.	13,150
Nov. 11, 1898	"	27	2 days.	13,140
Nov. 11, 1898	"	27	2 days.	13,140
Nov. 11, 1898	"	27	2 days.	14,350
Nov. 11, 1898	"	27	2 days.	14,600
Dec. 16, 1898	"	27	2 days.	13,380
Dec. 16, 1898	"	27	2 days.	13,560
Dec. 16, 1898	"	27	2 days.	14,000
Dec. 16, 1898	"	27	2 days.	14,330

PORTLAND CEMENT. — NEAT CEMENT. (Compression.) — *Concluded.*

Date of Test.	Brand.	Per cent. of Water Used in Mixing.	Time of Set.	Breaking Strength.
Dec. 16, 1898	Alsen.	27	2 days.	14,850
Dec. 16, 1898	"	27	2 days.	14,910
Dec. 16, 1898	"	27	2 days.	15,230
Jan. 6, 1899	"	27	2 days.	13,400
Jan. 6, 1899	"	27	2 days.	13,400
Jan. 6, 1899	"	27	2 days.	14,000
Dec. 21, 1898	"	27	5 days.	15,030
Dec. 21, 1898	"	27	5 days.	15,380
Dec. 21, 1898	"	27	5 days.	16,000
Dec. 21, 1898	"	27	5 days.	16,600
Dec. 21, 1898	"	27	5 days.	17,340
Dec 21, 1898	"	27	5 days.	17,370
Nov 14, 1898	"	27	7 days.	18,780
Nov. 14, 1898	"	27	7 days.	18,000
Nov. 14, 1898	"	27	7 days.	18,400
Nov. 14, 1898	"	27	7 days.	19,000
Nov. 14, 1898	"	27	7 days.	19,880
Jan. 9, 1899	"	27	7 days.	18,150
Jan. 9, 1899	"	27	7 days.	21,400
Jan. 9, 1899	"	27	7 days.	21,800
Nov. 16, 1898	"	27	14 days.	21,390
Nov. 16, 1898	"	27	14 days.	22,000
Nov. 16, 1898	"	27	14 days.	22,500
Jan. 11, 1899	"	27	1 mo.	22,600
Jan. 11, 1899	"	27	1 mo.	23,550
Jan. 11, 1899	"	27	1 mo.	25,400
Mar. 1, 1899	"	27	3 mos.	26,070
Mar. 1, 1899	"	27	3 mos.	23,730
June 6, 1899	"	27	6 mos.	36,280
June 6, 1899	"	27	6 mos.	46,400
Mar. 16, 1899	Saylor's.	24	2 days.	12,050
Mar. 16, 1899	"	24	2 days.	12,210
Mar. 16, 1899	"	24	2 days.	12,300
Mar. 16, 1899	"	24	2 days.	12,350
Mar. 16, 1899	"	24	2 days.	13,600
Mar. 16, 1899	"	24	7 days.	23,560
Mar. 16, 1899	"	24	7 days.	24,000
Mar. 16, 1899	"	24	7 days.	24,180
Mar. 16, 1899	"	24	7 days.	26,000
Mar. 16, 1899	"	24	7 days.	26,180
Dec. 20, 1898	"	24	7 days.	23,030
Mar. 13, 1899	"	24	7 days.	25,890
Mar. 13, 1899	"	24	7 days.	26,230
Mar. 25, 1899	"	24	14 days.	28,920
Mar. 25, 1899	"	24	14 days.	27,800
Mar. 25, 1899	"	24	14 days.	29,210
June 6, 1899	"	24	3 mos.	33,030
June 6, 1899	"	24	3 mos.	33,870
June 6, 1899	"	24	3 mos.	36,450
June 6, 1899	"	24	3 mos.	33,100

PORTLAND CEMENT.—SAND TESTS. (Tension.)

Date of Test.	Brand.	Parts Sand to one Part Cement.	Per cent. of Water Used in Mixing.	Time of Set.	Breaking Strength.
Nov. 20, 1897 . .	Atlas.	2	12	2 days.	80
Nov. 20, 1897 . .	"	2	12	2 days.	84
Nov. 20, 1897 . .	"	2	12	2 days.	86
Dec. 15, 1897 . .	"	2	12	2 days.	94
Nov. 24, 1897 . .	"	2	12	6 days.	230
Dec. 9, 1897 . .	"	2	12	7 days.	260
Dec. 13, 1897 . .	"	2	12	7 days.	278
Dec. 13, 1897 . .	"	2	12	7 days.	279
Dec. 13, 1897 . .	"	2	12	7 days.	290
Dec. 13, 1897 . .	"	2	12	7 days.	320
Dec. 13, 1897 . .	"	2	12	7 days.	290
Nov. 16, 1898 . .	"	2	12	1 year.	469
Dec. 23, 1898 . .	"	2	12	1 year.	360
Dec. 23, 1898 . .	"	2	12	1 year.	360
Dec. 23, 1898 . .	"	2	12	1 year.	398
Dec. 5, 1898 . .	Alsen.	3	12	3 days.	109
Dec. 5, 1898 . .	"	3	12	3 days.	121
Dec. 12, 1808 . .	"	3	12	3 days.	101
Dec. 12, 1808 . .	"	3	12	3 days.	106
Dec. 12, 1898 . .	"	3	12	3 days.	111
Dec. 12, 1898 . .	"	3	12	3 days.	118
Dec. 19, 1898 . .	"	3	12	7 days.	170
Dec. 19, 1898 . .	"	3	12	7 days.	181
Dec. 19, 1898 . .	"	3	12	7 days.	182
Dec. 19, 1868 . .	"	3	12	7 days.	191
Dec. 19, 1898 . .	"	3	12	7 days.	212
Dec. 19, 1898 . .	"	3	12	7 days.	245
Dec. 2, 1898 . .	"	3	12	14 days.	250
Dec. 2, 1898 . .	"	3	12	14 days.	253
Dec. 2, 1898 . .	"	3	12	14 days.	255
Dec. 2, 1898 . .	"	3	12	14 days.	284
Jan. 9, 1899 . .	"	3	12	1 mo.	258
Jan. 9, 1899 . .	"	3	12	1 mo.	260
Jan. 9, 1899 . .	"	3	12	1 mo.	320
Mar. 23, 1899 . .	Saylor's.	3	12	2 days.	68
Mar. 23, 1899 . .	"	3	12	2 days.	72
Mar. 25, 1899 . .	"	3	12	7 days.	146
Mar. 27, 1899 . .	"	3	12	7 days.	143
Mar. 27, 1899 . .	"	3	12	7 days.	138
Mar. 29, 1899 . .	"	3	12	7 days.	135
Mar. 29, 1099 . .	"	3	12	7 days	134
Mar. 30, 1899 . .	"	3	12	12 days.	130
Mar. 30, 1899 . .	"	3	12	12 days.	138
Mar. 30, 1899 . .	"	3	12	12 days.	160
June 12, 1899 . .	"	3	12	2 mos.	205
June 12, 1899 . .	"	3	12	2 mos.	210
June 12, 1899 . .	"	3	12	2 mos.	225
June 12, 1899 . .	"	3	12	2 mos.	245

PORTLAND CEMENT.—SAND TESTS. (Compression.)

Date of Test.	Brand.	Parts Sand to one Part Cement.	Per cent. of Water Used in Mixing.	Time of Set.	Breaking Strength.
Nov. 20, 1897 . .	Atlas.	2	12	2 days.	2,550
Nov. 20, 1897 . .	"	2	12	2 days.	2,700
Nov. 20, 1897 . .	"	2	12	2 days.	3,190
Nov. 19, 1897 . .	"	2	12	7 days.	6,240
Nov. 19, 1897 . .	"	2	12	7 days.	7,150
Nov. 24, 1897 . .	"	2	12	7 days.	6,030
Nov. 24, 1897 . .	"	2	12	7 days.	6,030
Nov. 24, 1897 . .	"	2	12	7 days.	7,080
Nov. 24, 1897 . .	"	2	12	7 days.	7,120
Dec. 10, 1897 . .	"	2	12	7 days.	6,290
Dec. 13, 1897 . .	"	2	12	7 days.	6,820
Dec. 13, 1897 . .	"	2	12	7 days.	7,600
Dec 13, 1897 . .	"	2	12	7 days.	7,700
Dec. 13, 1897 . .	"	2	12	7 days.	7,700
Dec. 13, 1897 . .	"	2	12	7 days.	8,150
Nov. 16, 1898 . .	"	2	12	1 year.	17,250
Dec. 20, 1898 . .	"	2	12	1 year.	16,790
Dec. 20, 1898 . .	"	2	12	1 year.	17,270
Dec. 23, 1898 . .	"	2	12	1 year.	22,000
Dec. 23, 1898 . .	"	2	12	1 year.	19,220
Dec. 23, 1898 . .	"	2	12	1 year.	17,700
Dec. 23, 1898 . .	"	2	12	1 year.	20,750
Dec. 23, 1893 . .	"	2	12	1 year.	22,000
Dec. 5, 1898 . .	Alsen.	3	12	3 days.	2,620
Dec. 5, 1898 . .	"	3	12	3 days.	3,030
Dec. 5, 1898 . .	"	3	12	3 days.	3,250
Dec. 5, 1898 . .	"	3	12	3 days.	3,158
Dec. 12, 1898 . .	"	3	12	3 days.	2,600
Dec. 12, 1898 . .	"	3	12	3 days.	2,640
Dec. 12, 1898 . .	"	3	12	3 days.	2,810
Dec. 19. 1898 . .	"	3	12	7 days.	4,350
Dec. 19, 1898 . .	"	3	12	7 days.	4,520
Dec. 19, 1898 . .	"	3	12	7 days.	4,760
Dec. 19, 1898 . .	"	3	12	7 days.	4,230
Dec. 19, 1898 . .	"	3	12	7 days.	4,750
Dec. 19, 1898 . .	"	3	12	7 days.	4,900
Dec. 2, 1898 . .	"	3	12	14 days.	4,470
Dec. 2, 1898 . .	"	3	12	14 days.	4,490
Dec. 2, 1898 . .	"	3	12	14 days.	4,780
Mar. 23, 1899 . .	Saylor's.	3	12	2 days.	1,540
Mar. 23, 1899 . .	"	3	12	2 days.	1,580
Mar. 23, 1899 . .	"	3	12	2 days.	1,690
Mar. 23, 1899 . .	"	3	12	2 days.	1,910
Mar. 25, 1899 . .	"	3	12	7 days.	3,820
Mar. 27, 1899 . .	"	3	12	7 days.	4,200
Mar. 27, 1899 . .	"	3	12	7 days.	4,320
Mar. 27, 1899 . .	"	3	12	7 days.	4,290
Mar. 27, 1899 . .	"	3	12	7 days.	4,580
Mar. 29, 1899 . .	"	3	12	7 days.	3,880
Mar. 29, 1899 . .	"	3	12	7 days.	4,180
June 12, 1899 . .	"	3	12	2 mos.	4,500
June 12, 1899 . .	"	3	12	2 mos.	4,700
June 12, 1899 . .	"	3	12	2 mos.	5,150

Tests on Building Brick.

This set of tests was undertaken to find the crushing strength of common building bricks when tested separately, and was made on a 300,000 pounds Emery testing machine.

Three series of tests were made: the first on Dover River hard and soft burned bricks; the second on Central New York hard, medium, and soft burned bricks; and the third on some hard burned bricks which were stored in the basement of the Engineering Laboratory at the Institute. In all these tests the bearing surfaces were set in neat Portland cement which was smoothed off to a plane surface, to provide an even bearing for the bricks against the platforms of the testing machine.

In the first and second series of tests the pressure was applied to the broad surfaces of the bricks, and the tables which follow give the area of the cross section, or the bearing area, the maximum load on the brick, and the maximum load per square inch.

The third series was made in order to compare the breaking load per square inch, obtained by applying the pressure to the broad surfaces, with that obtained by applying the pressure to the edge of the bricks. The tables give the results in the same form as for the preceding series.

In nearly all the tests the amount of water which the bricks would absorb was ascertained and is given in the last column of the tables. The bricks were weighed when dry and then immersed in water until no further gain in weight was obtained, and then weighed again. The amount of water absorbed is given in per cent. of the weight of the dry brick. Time enough was allowed for the cement to set and for the bricks to dry out thoroughly before the tests were made.

DOVER RIVER. (Soft Burned.)

Number of Test.	Area of Cross Section. (Sq. in.)	Maximum Load. (Lbs.)	Maximum Load. (Lbs. per sq. in.)	Amount of Water Absorbed. (Per cent.)
1	28.4	135,000	4,750	13.2
2	28.5	175,000	6,140	14.2
3	29.4	140,000	4,760	....
4	28.5	146,000	5,140	14.7
5	29.4	132,000	4,490	13.1
6	28.0	148,000	5,290	....
7	29.0	163,000	5,620	....
8	29.0	173,000	5,970	....
9	29.0	151,000	5,210	14.8
10	29.0	138,000	4,760	15.7
11	28.0	178,000	6,360	13.1
12	28.0	170,000	6,070	12.2
13	29.0	119,000	4,100	16.6
14	29.0	132,000	4,550	14.9
15	28.5	144,000	5,050	....
16	30.5	124,000	4,070	17.0
17	29.5	138,000	4,680	12.2
18	28.1	183,000	6,510	13.9
19	29.0	136,000	4,690	18.6
20	27.8	240,000	8,630	12.3
21	28.5	208,000	7,300	12.3
22	28.8	180,000	6,250	12.5
23	27.1	220,000	8,120	11.6
24	28.5	169,000	5,930	15.7
25	29.0	126,000	4,340	12.6
26	29.0	142,000	4,900	13.0
27	29.5	158,000	5,360	14.0
28	29.0	139,000	4,790	....
29	28.1	173,000	6,150	....
30	28.5	188,000	6,600	14.4
31	29.5	166,000	5,630	13.3
32	29.7	193,000	6,500	14.9
33	29.0	178,000	6,140	....
34	28.5	151,000	5,300	....
35	28.1	131,000	4,650	....
36	30.7	159,000	5,180	....
37	28.1	174,000	6,200	....
38	28.5	112,000	3,930	....
Average			5,530	14.0
Maximum			8,630	18.6
Minimum			3,930	11.6

DOVER RIVER. (Hard Burned.)

Number of Test.	Area of Cross Section. (Sq. in.)	Maximum Load. (Lbs.)	Maximum Load. (Lbs. per sq. in.)	Amount of Water Absorbed. (Per cent.)
1	26.2	206,000	7,860	6.0
2	25.8	240,000	9,300	5.4
3	27.6	189,000	6,850	7.6
4	27.6	231,000	8,370	6.5
5	27.3	199,000	7,290	6.2
6	26.2	167,000	6,370	6.8
7	28.1	210,000	7,470	6.6
8	26.9	181,000	6,730	6.7
9	27.8	203,000	7,300	8.9
10	26.4	230,000	8,710	5.8
11	27.1	288,000	10,630	8.5
12	26.6	207,000	7,770	10.1
13	26.9	183,000	6,800	6.5
14	27.1	220,000	8,120	6.2
15	27.1	221,000	8,150	6.4
16	25.7	245,000	9,530	4.7
17	25.6	280,000	10,940	...
19	26.4	262,000	9,920	6.0
20	26.6	260,000	9,770	7.6
21	27.1	202,000	7,520	7.0
22	26.6	186,000	6,990	7.1
24	26.4	219,000	8,310	5.8
25	29.0	170,000	5,850	9.9
26	26.2	231,000	8,800	5.2
27	27.1	177,000	6,520	6.8
28	28.4	191,000	6,730	9.0
29	26.6	197,000	7,400	6.7
30	27.1	204,000	7,530	6.8
32	28.8	254,000	8,820	6.8
33	24.9	234,000	9,400	...
34	27.1	239,000	8,820	7.8
35	28.8	220,000	7,640	9.0
36	28.0	231,000	8,250	7.8
Average			8,070	7.0
Maximum			10,940	10.1
Minimum			5,850	4.7

CENTRAL NEW YORK. (Soft Burned.)

Number of Test.	Area of Cross Section. (Sq. in.)	Maximum Load. (Lbs.)	Maximum Load. (Lbs. per sq. in.)	Amount of Water Absorbed. (Per cent.)
1	34.3	63,000	1,840	19.6
2	33.5	61,000	1,820	20.9
3	33.5	75,000	2,240	19.3
4	34.0	60,000	1,800	20.0
5	33.3	69,000	2,070	18.7
6	34.5	77,000	2,230	18.9
7	33.5	59,000	1,760	21.7
8	34.3	47,000	1,370	21.5
9	33.0	81,000	2,460	17.8
10	33.0	83,000	2,510	18.0
11	33.3	78,000	2,350	18.9
12	33.3	60,000	1,800	21.1
13	33.5	76,000	2,270	19.5
14	33.0	77,000	2,330	19.1
15	33.3	69,000	2,070	21.9
16	33.3	61,000	1,830	21.0
17	33.5	73,000	2,180	18.9
18	33.3	64,000	1,920	20.5
19	33.0	75,000	2,270	19.8
20	33.0	80,000	2,420	20.7
21	33.3	58,000	1,740	20.7
22	33.3	71,000	2,130	19.8
23	33.3	76,000	2,280	19.6
24	31.0	91,000	2,930	18.7
25	33.3	84,000	2,520	18.2
26	33.5	83,000	2,490	19.2
27	33.5	72,000	2,150	20.5
28	33.0	76,000	2,300	19.1
29	33.0	77,000	2,320	19.9
30	32.4	63,000	1,640	21.9
31	33.0	71,000	2,150	22.0
32	32.5	77,000	2,380	18.7
33	33.7	75,000	2,220	20.3
34	33.5	97,000	2,900	19.2
35	33.5	73,000	2,100	22.2
36	33.7	103,000	3,060	19.8
Average			2,190	19.9
Maximum			3,060	22.0
Minimum			1,370	17.8

CENTRAL NEW YORK. (Medium.)

Number of Test.	Area of Cross Section. (Sq. in.)	Maximum Load. (Lbs.)	Maximum Load. (Lbs. per sq. in.)	Amount of Water Absorbed. (Per cent.)
1	32.2	108,000	3,360	17.6
2	31.7	104,000	3,280	16.6
3	32.2	110,000	3,420	16.9
4	31.7	126,000	3,970	16.7
5	32.2	109,000	3,390	23.4
6	31.7	105,000	3,310	17.7
7	31.5	120,000	3,810	17.3
8	31.5	88,000	2,800	20.4
9	31.7	129,000	4,080	16.7
10	32.9	127,900	3,860	18.4
11	31.5	118,000	3,750	18.0
12	31.2	99,000	3,170	20.8
13	31.5	104,000	3,300	18.1
14	32.2	122,000	3,780	18.3
15	32.0	105,000	3,280	18.0
16	31.2	121,000	3,880	18.3
17	31.2	94,000	3,000	18.5
18	31.5	87,000	2,080	20.8
19	32.5	129,000	3,970	18.7
20	32.5	123,000	3,790	19.0
21	31.7	121,000	3,820	19.6
22	31.0	85,000	2,740	20.9
23	31.2	135,000	4,330	18.2
24	32.2	116,000	3,600	19.2
25	31.5	126,000	4,000	18.1
26	31.2	100,000	3,210	20.9
27	32.0	133,000	4,160	18.4
28	31.7	157,000	4,950	18.5
29	31.5	119,000	3,780	19.0
30	32.0	116,000	3,620	18.6
31	31.7	102,000	3,220	18.7
32	32.7	123,000	3,760	18.2
23	31.7	129,000	4,070	18.1
34	31.0	115,000	3,710	16.9
Average			3,600	18.6
Maximum			4,950	23.4
Minimum			2,080	16.6

CENTRAL NEW YORK. (Hard Burned.)

Number of Test.	Area of Cross Section. (Sq. in.)	Maximum Load. (Lbs.)	Maximum Load. (Lbs. per sq. in.)	Amount of Water Absorbed. (Per cent.)
2	31.0	120,000	3,870	16.7
3	30.2	100,000	3,310	11.7
4	29.5	146,000	4,950	13.6
5	29.5	194,000	6,580	10.9
6	29.5	198,000	6,710	11.0
7	31.7	135,000	4,260	13.9
8	31.4	160,000	5,100	12.0
9	30.0	193,000	6,430	10.4
10	32.5	160,000	4,920	14.2
11	31.5	227,000	7,210	9.4
12	31.2	275,000	8,810	8.3
13	31.0	149,000	4,810	15.0
14	31.2	202,000	6,470	10.1
15	30.4	162,000	4,170	15.1
16	31.2	130,000	5,330	16.4
17	28.3	132,000	4,670	15.0
18	28.8	135,000	4,690	12.3
19	29.3	171,000	5,840	10.2
20	28.3	173,000	6,110	12.8
21	29.1	166,000	5,700	11.8
22	28.6	174,000	6,080	12.5
23	31.2	190,000	6,090	12.5
24	30.7	187,000	6,090	12.5
26	30.5	212,000	6,950	13.0
27	28.3	123,000	4,340	10.3
29	28.4	164,000	5,780	11.3
30	31.0	134,000	4,320	....
31	31.4	130,000	4,140	....
32	29.1	162,000	5,570	10.2
33	31.8	123,000	3,870	14.1
34	32.5	132,000	4,060	14.4
35	30.8	139,000	4,510	11.9
36	32.5	168,000	5,170	13.4
Average			5,360	12.5
Maximum			8,810	16.7
Minimum			3,310	8.3

HARD BURNED BRICKS STORED IN BASEMENT OF LABORATORY.

Number of Test.	Area of Cross Section. (Sq. in.)	Maximum Load. (Lbs.)	Maximum Load. (Lbs. per sq. in.)	Amount of Water Absorbed. (Per cent.)
2	30.5	220,000	7,210	11.0
3	30.0	221,000	7,370	12.0
4	30.7	204,000	6,650	12.0
5	31.2	205,000	6,570	11.0
6	30.7	263,000	8,560	8.8
7	31.2	250,000	8,010	10.7
9	30.7	300,000	9,770	10.1
10	30.7	210,000	6,840	12.3
12	31.5	249,000	7,900	10.7
13	31.2	258,000	8,270	10.6
14	30.2	223,000	7,380	12.9
15	29.2	272,000	9,320	7.6
16	29.3	274,000	9,350	7.6
Average			7,940	10.6
Maximum			9,770	12.9
Minimum			6,570	7.6
17	18.3	98,000	5,350	13.2
18	17.6	180,000	10,230	6.2
19	18.1	109,000	6,020	11.0
20	18.6	91,000	4,890	12.8
21	18.9	98,000	5,180	12.6
23	18.8	98,000	5,210	10.9
24	19.6	108,000	5,510	12.9
25	19.1	106,000	5,560	12.1
26	18.6	163,000	8,760	9.9
27	19.6	75,000	3,830	12.8
28	19.4	116,000	5,980	11.0
29	17.9	131,000	7,320	18.7
30	18.7	86,000	4,600	10.1
31	18.0	171,000	9,500	7.4
32	18.0	152,000	8,440	9.4
Average			6,430	11.4
Maximum			10,230	18.7
Minimum			3,830	6.2

NOTE. — In tests Nos. 2–16 the pressure was applied to the broad surface, and in tests Nos. 17–32 the pressure was applied to the edge of the bricks.

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THE RECTANGULAR SYSTEM OF UNITED STATES PUBLIC LAND SURVEYING.

BY CHARLES L. DU BOIS, C. E., CHIEF OF DIVISION OF PUBLIC SURVEYS, GENERAL LAND OFFICE.

IT is a well known fact that among civil engineers of this country the theory and practice of public land surveying is not thoroughly understood, and the admirable features of the rectangular method have not received the recognition they deserve.

In the bulky volumes of the great trigonometrical survey of India, which work was accomplished many years ago at an expenditure of years of labor and thousands of pounds sterling, we see an accurate record of a magnificent scientific achievement, the result of which has been that that far-off region is faithfully mapped and monumented for future generations, and the configuration of such a vast territory so clearly determined as to have a bearing upon the ascertainment of the exact shape of the globe itself. Such a result is valuable for scientific and strategical purposes, but has not the economic uses of our public land survey system.

In the public domain of our country a plan, which became the law, was devised by a Committee of the Continental Congress, headed by Thomas Jefferson, whereby the unoccupied and unappropriated land could be so divided up as to enable settlers to obtain equitable portions of the land, and so fix and determine the boundaries of the smallest tract that no confusion or conflict would arise. The wisdom

of this plan is made manifest every day. Over the great plains and rich valleys, as well as the rugged sides of the Rockies, there are symmetrical squares of land definitely and accurately described, not by metes and bounds, but by location, which contain forty, eighty, and one hundred and sixty acre tracts, the homes of the millions now domiciled, and the countless numbers yet to come, upon the vast domain which fifty years ago was an unbroken wilderness inhabited by red men and buffaloes. This plan has been modified and improved by various acts of Congress, but the inceptional design has not been changed.

A few years ago our Canadian brethren found themselves confronted by the problem of dividing up their own extensive territory in preparation for the settlement by the constantly increasing squatters in the British Possessions; and it was a high compliment to the rectangular system of United States public land surveys when they adopted practically our methods. To be sure, there were one or two so-called improvements made by them, but they are minor changes, and their utility has been questioned by experts.

The *United States Coast and Geodetic Survey* has charge of the survey of the Atlantic, Gulf, and Pacific coasts of this country, including the coasts of Alaska, the survey of rivers to the head of tide-water or ship navigation; deep-sea soundings, temperature and current observations along the said coasts and throughout the Gulf Stream and Japan Stream flowing off from them; magnetic observations and gravity researches, determinations of heights by geodetic leveling, and of geographical positions by lines of transcontinental triangulation which, with other connecting triangulations and observations for latitude, longitude, and azimuth, furnish points of reference for State surveys and connect the work on the Atlantic coast with that on the Pacific.

The *United States Geological Survey* has charge of the classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain, and of survey of boundaries of forest reserves.

The *Hydrographic Survey* under the Department of the Navy is engaged upon the preparation of maps of foreign coasts and harbors for the use of our navigators.

The *Nautical Almanac* office, under the same department, prepares valuable tables and formulæ showing right ascensions, declinations, occultations of the heavenly bodies, for use of navigators and for gen-

eral scientific use in surveying operations demanding astronomical observations.

Upon the Commissioner of the General Land Office devolves the important duty of carrying forward the public land surveys, and under him the direction of the work is entrusted to the Division of Public Surveys of that office.

The surveying is done principally under contract with experienced engineers who are called deputy surveyors. In each of the surveying districts of the West, viz., Arizona, California, Nevada, Oregon, Washington, Idaho, Utah, New Mexico, Colorado, Montana, Wyoming, North Dakota, South Dakota, Minnesota and Alaska, a Surveyor General is appointed by the President, with authority to make contracts for surveys, subject to the approval of the Commissioner of General Land Office. He has in his office clerks and draftsmen who prepare the finished returns for transmittal to Washington. The sum of $325,000 is annually appropriated by Congress to pay for the surveys, which is exclusive of the amounts set apart by Congress for the salaries and expenses of the Surveyors General and their corps of clerks.

The Rectangular System.

"Existing law requires that in general the public lands of the United States 'shall be divided by north and south lines run according to the true meridian, and by others crossing them at right angles so as to form townships 6 miles square,' and that the corners of the townships thus surveyed 'must be marked with progressive numbers from the beginning.'

"Also, that the townships shall be subdivided into thirty-six sections, each of which shall contain 640 acres, as nearly as may be, by a system of two sets of parallel lines, one governed by true meridians and the other by parallels of latitude, the latter intersecting the former at right angles, at intervals of a mile.

"In the execution of the public surveys under existing law, it is apparent that the requirements that the lines of survey shall conform to true meridians, and that the townships shall be 6 miles square, taken together, involve a mathematical impossibility due to the convergency of the meridians.

"Therefore, to conform the meridional township lines to the true meridians, produces townships of a trapezoidal form which do not contain the precise area of 23,040 acres required by law, and which dis-

crepancy increases with the increase in the convergency of the meridians, as the surveys attain the higher latitudes.

"In view of these facts, and under the provisions of Section 2 of the Act of May 18, 1796, that sections of a mile square shall contain 640 acres *as nearly as may be*, the public lands of the United States are surveyed under the methods of the system of rectangular surveying, which harmonizes the incompatibilities of the requirements of law and practice, as follows:

"*First.* The establishment of a principal meridian conforming to the true meridian, and at right angles to it, a base line conforming to a parallel of latitude.

"*Second.* The establishment of standard parallels conforming to parallels of latitude, initiated from the principal meridian at intervals of 24 miles and extended east and west of the same.

"*Third.* The establishment of guide meridians conforming to true meridians, initiated upon the base line and successive standard parallels at intervals of 24 miles, resulting in tracts of land 24 miles square, *as nearly as may be*, which are subsequently divided into tracts of land 6 miles square by two sets of lines, one conforming to true meridians, crossed by others conforming to parallels of latitude at intervals of 6 miles, containing 23,040 acres, *as nearly as may be*, and designated *townships*.

"Any series of contiguous townships situated north and south of each other, constitute a *range*, while such a series situated in an east and west direction constitute a *tier*.

"The tiers of townships are numbered to the north or south, commencing with No. 1 at the base line, and the ranges of the townships to the east or west, beginning with No. 1 at the principal meridian of the system.

"The thirty-six sections into which a township is subdivided are numbered, commencing with number *one* at the *northeast* angle of the township, and proceeding west to number six, and thence proceeding east to number twelve, and so on, alternately, to number thirty-six in the southeast angle. In all cases of surveys of fractional townships, the sections bear the same numbers they would have if the township were full.

"Standard parallels are established at intervals of every 24 miles north and south of the base line, and guide meridians at intervals of every 24 miles east and west of the principal meridians, thus confin-

ing the errors resulting from convergence of meridians and inaccuracies in measurement within comparatively small areas." — *Manual of Surveying Instructions, 1894.*

How Public Land Surveys are Initiated.

In order to obtain a survey of public land, application is made to the Surveyor General of the district where the lands are situated, by settlers, at least three for every tract 6 miles square, whose petition must set forth that they are *bona fide* settlers, and that they have made valuable improvements. The Surveyor General forwards the petition to the General Land Office at Washington and asks for authority to contract for a survey of the land. If the application be properly supported, the Surveyor General is instructed to take the necessary steps to have the survey made.

If there appear to be involved the payment of the minimum or intermediate rates, which are hereinafter explained, the Surveyor General can at once enter into contract with a reputable surveyor to be selected by him, for an amount of work not to exceed $5,000, which is estimated to be the maximum that one surveyor can absorb in a surveying season. No sub-letting of contracts is allowed. This limit can be increased to $8,000, which amount is allowed two surveyors in a *joint* contract.

Should the character of the proposed survey involve the maximum rates, the Surveyor General is required to invite proposals and competitive bids from reliable and experienced surveyors, and advertisements are inserted in local papers, showing the estimated amount and description of the survey. Where the surveyor is unknown to the General Land Office, he is required to file evidence of his qualifications to complete the work.

Where no competitive bids are required, the contracts are prepared and forwarded to the Commissioner of the General Land Office for his approval, but where bids are submitted, they are all sent to the Commissioner by the Surveyor General, with a recommendation as to the lowest bidder.

The Commissioner transmits the bids to the Secretary of the Interior, who alone has authority to allow the increased rates, and after the latter has granted permission to allow the rates and approved the selection of the bidder, the Commissioner instructs the Surveyor General to award the contract. This contract must, however, receive

official sanction by the Commissioner before the work can be entered upon.

Contracts always specify the exact number of miles to be run, and the rates to be allowed for the classes of lines. Of course it is impossible to estimate in advance, how much of the survey will be obstructed and rendered difficult by the lands being heavily timbered, or mountainous, and the complete field notes of the work are necessary to show this.

It will be observed by the practical surveyor that here is an opportunity for impositions to be practiced upon the government, for a line may be returned as exceptionally difficult to survey, when in fact it is unobstructed by any natural obstacles. However, by the system of inspections to be hereafter described, such frauds are detected. Deputies who have been found making false statements as to difficulties encountered or in respect to evidences of surveys are disbarred from future work under the government.

Rates for Contract Surveys.

The payment for surveys made under contract is in accordance with the provisions of annual appropriations by Congress for surveys and resurveys of public lands. The rates are thus fixed by Congressional enactment and do not change from year to year. Surveyors are allowed a compensation by the mile for each mile actually run and marked in the field.

Twenty-five years ago the rates were greater than at present, for obvious reasons. Difficulties attending transportation of supplies and higher prices for provisions and equipment, made the surveyor's profit about equal to the present time.

In fixing the rates, allowance was made for increased difficulties encountered by the surveyor in establishing lines in a mountainous region, and the more important lines requiring greater care to establish were rated higher than subdivisional lines.

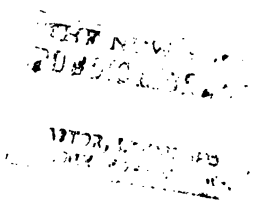
There are now nine classes of rates as follows:

Minimum Rates.

For surveys and resurveys of lands offering no obstruction to the surveyor, such as in prairie country.

$5.00 per mile for section lines.
7.00 per mile for township lines.
9.00 per mile for standard and meander lines.

FIG. 1. — U. S. DEPUTY SURVEYOR.
Showing bearing tree and quarter-section post.



Intermediate Rates.

For surveys and resurveys of lands heavily timbered, mountainous, or covered with dense undergrowth.

$7.00 per mile for section lines.
11.00 per mile for township lines.
13.00 per mile for standard, base, and meander lines.

Maximum Rates.

For surveys and resurveys of lands exceptionally difficult to survey where the intermediate rates can not be contracted for.

$12.00 per mile for section lines.
15.00 per mile for township and range lines.
18.00 per mile for standard, base, and meander lines.

Special Maximum Rates.

Allowed only in States and Territories west of and embracing the Rocky Mountains, for the survey and resurvey of lands heavily timbered, mountainous, or covered with dense undergrowth.

$20.00 per mile for section lines.
23.00 per mile for township lines.
25.00 per mile for standard, base, and meander lines.

The above presents a good idea of the grading of the rates paid contractors.

In certain States, such as California, surveys may be contracted for at a *per diem* compensation, the contract fixing the limit of the liability. This is to provide for surveys which cannot be contracted for at the mileage rates, such as small groups of surveys remote from lines of travel. Contracts are made for such work at $25.00 to $40.00 per day, the total cost not to exceed a certain sum.

Corner Monuments.

There are over one hundred varieties of corners prescribed for marking the lines of public land surveys. This seems at first glance to be a rather cumbrous system, but it is the result of an attempt to differentiate the classes of lines and to conform to the conditions found upon the tract surveyed, the desiderata being to plant the most durable monuments without imposing upon the government the cost of transporting materials over great distances.

The great variety is accounted for as follows:

The surveyor is required to establish one of eight kinds of corners, varying according to the character of the ground, and the practicability of securing materials at the points determined, viz.:

First, the *stone corner with pits and mound of earth.* This corner is placed in a cleared space where the earth can be removed.

Second, the *stone corner with mound of stone.* This is placed in open country, in rocky soil where pits are impracticable.

When the point for corner comes in timber, the

Third kind is established: a *stone with bearing trees.*

This corner is considered the best and most durable of all corners. In regions where stone does not abound there is placed the

Fourth kind of corner, which is a *post with pits and mound of earth*, placed in open spaces, but, if corner point come in timber, there is placed the

Fifth kind: a *post with bearing trees.*

If, however, nothing is obtainable with which to make suitable post, and the surveyor is unable to ship to the point proper material, he is allowed to establish the

Sixth kind: a *mound of earth with deposit and stake in pit.*

This corner is considered to be inferior to any other, as its perpetuity is dependent upon its memorials placed under the mound and the small stake in pit. It sometimes happens that a tree is found at the precise point for corner, in which case the

Seventh kind is established. That is, the tree is marked and suitably witnessed by pits and mound of earth, and if the tree is in the midst of others, the

Eighth kind of corner is established, involving the marking of bearing trees.

Differentiation of Corners.

The above described corners comprise those which must be built contingent upon prescribed conditions; they are easily remembered and involve no complications, but the surveyor has something more to learn beside the marking, size, shape, and limits of the above; he must *vary these corners* according to the class of lines he is engaged upon surveying.

There are thirteen classes of corners which govern the kind of monuments. They are:

Standard township corners.
Closing township corners.
Corners common to four townships.
Corners common to two townships.
Corners referring to one township.
Meander corners.

Standard section corners.
Closing section corners.
Corners common to four sections.
Corners common to two sections.
Corners referring to one section.
Quarter section corners.

Reservation corners.

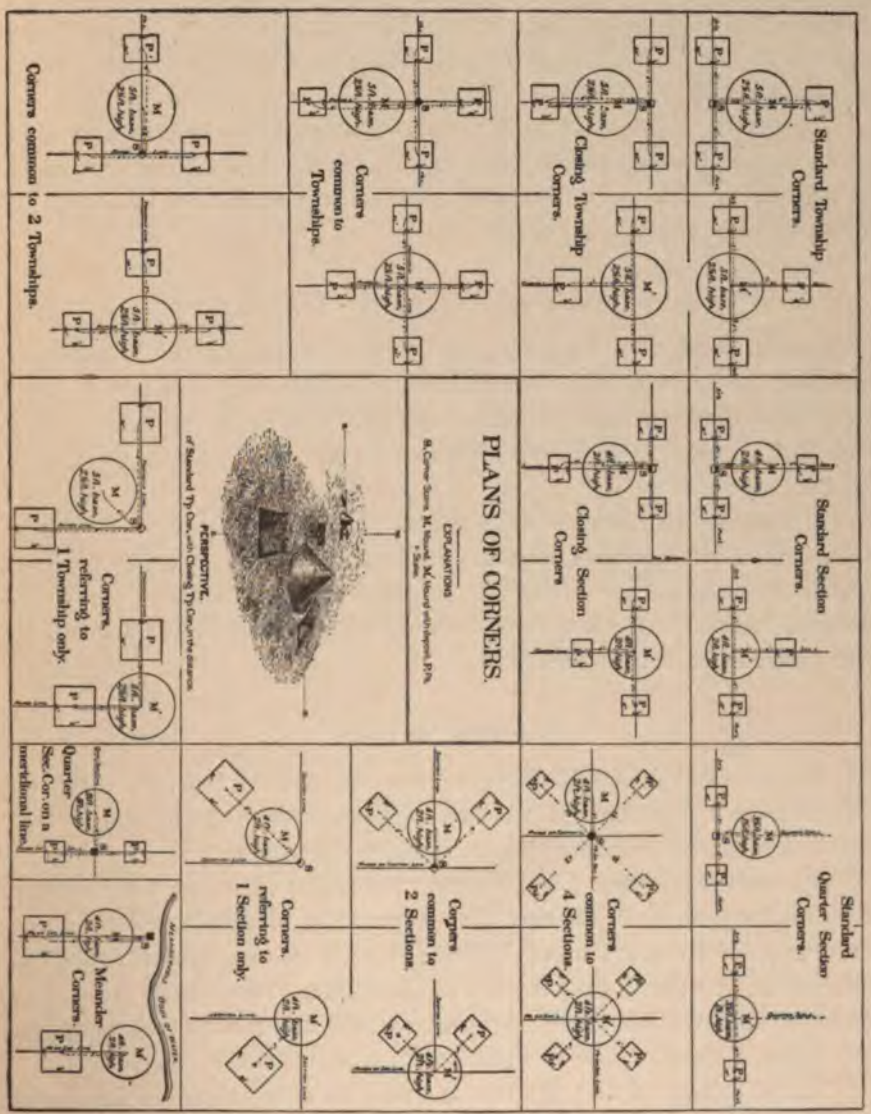


FIG. 2.—GROUND PLANS OF CORNERS OF U. S. PUBLIC LAND SURVEYS.

Now if each monument must have an appropriate size and shape, and the pits be placed differently for each one of the thirteen classes, it follows that the surveyor must be familiar with the construction of 104 kinds of corners in order to be properly equipped for his duties.

In examining candidates for the position of inspector of contract surveys of public lands, it has been found practically impossible to obtain surveyors possessing the necessary qualifications among those who have never been in the field either as deputy surveyors or as chainmen with examiners of surveys.

To young engineers who have in view the undertaking of this kind of surveying I would say, engage as a subordinate in a surveying party for a season and learn thus the conditions peculiar to the work of running lines of public surveys.

Base Lines and Standard Parallels.

It will be at once observed that these lines from which township exteriors are run must be very carefully established, and the instructions and requirements to deputies who attempt such surveys are very full and specific. They must be run as near as possible on a true latitude curve.

If a true meridian be determined at every set up of the solar transit at short intervals, and a right angle be turned, a close approximation to the latitude curve will be attained, but in many cases it is deemed impracticable to pursue this method, and the lines are run by the tangent or secant methods.

Secant Method.

The method of establishing corners on a true latitude curve by offsets from a line situated between and parallel to the chord and tangents was devised to meet the demand for short offsets.

It consists of running out a connected series of straight lines, each 6 miles long, on such courses that any one of the lines will intersect the curve of the parallel of latitude in two points, separated by an interval of 4 miles; and from the lines thus established, measuring north or south, as the case may be, to attain other required points on the latitude curve. The straight lines are called secants.

The direction of the first secant will be determined at its initial point by observation on Polaris, and similar observations are made at

intervals of not exceeding 18 miles, while observations are made when practicable every night to guard against mistakes, detect errors, and check the direction of the line. The correct establishment of a standard parallel of offsets from secant lines depends upon:

1. Accuracy of observations on Polaris.
2. Close measurement of the azimuth angle, to define the initial direction of the secant.
3. Careful prolongation of the secant in a straight line.
4. Correct measurement of the deflection angle.

The secant method adapted to transit instruments exclusively, is recommended for its simplicity and accuracy, and the facility with which the line may be extended over rough mountainous land through dense undergrowth; in deep valleys or canyons where the sun cannot be observed in favorable positions, or anywhere during the continuance of adverse weather conditions and under circumstances where the use of solar apparatus would be, if not impossible, at least inconvenient and unreliable.

Tables showing the azimuths of the tangent to the parallel are furnished the surveyor. They are calculated for latitudes 30° to 50° and for each mile point of 12 miles.

Tangent Method.

This method consists in laying off from a true meridian, established by observations on Polaris, an angle of 90° producing the direction thus determined, a distance of 6 miles in a straight line, and measuring north therefrom, at half mile intervals, distances of correct length, taken from tables furnished to deputies for the latitude, to attain other points on the latitude curve passing through the tangential or initial point.

Instruments.

The requirements of the government in the use of instruments in running lines of public land surveys, provide that a solar transit or solar compass shall be employed, and that it shall be run independently of the magnetic needle.

In former times the kind of instrument was not prescribed, and great attention was paid to the variation of the needle. Much literature was furnished bearing upon the diurnal fluctuations of the mag-

netic needle, the annual changes in the magnetic declination and the shifting of the isogonic lines by the lapse of years. Many of the old surveys were executed with the needle compass and the variation either assumed or erroneously calculated. In consequence, the reliability of the surveys was much impaired by reason of local magnetic attraction, the carelessness of deputies, and the consciousness that no field examination would take place.

To avoid this state of things it was resolved to adopt and require the use of an instrument operating by other means than by the needle. Burt's Solar Compass was at first employed, and for twenty years was the only instrument adaptable to finding a meridian by observation upon the sun, which was practicable for field use, and to-day the principles upon which all solar transits used in public land surveying are constructed and the forms of attachments are identical with those of Burt's invention.

By this ingenious contrivance the surveyor can set his compass or transit over any point, and if the sun be shining, he can in five minutes direct his line of sight to a point precisely north or south or east and west of him. All that is necessary for him to know is the approximate latitude and longitude of the place, and the declination of the sun.

Aside from the original Burt's Solar Compass, which is an open sight apparatus, there are several instruments used in public land surveys made by different manufacturers. Gurley & Company use the Jones patent latitude arc, and their telescope carries the declination arc giving the sun's image as in the original Burt's compass. Young & Sons employ an ordinary railroad transit with Smith's Solar Attachment, which consists of an auxiliary telescope carrying a declination arc, and having a counterpoise. The image in this attachment is considerably increased in size, being several times larger than in the Gurley instrument. Keuffel, Esser & Company, manufacture the Saegmüller Solar Attachment to their solar transits.

There are other devices for solar work made as attachments to engineer's transits, which will not be described. Surveyors are divided in their preferences among these instruments, and it is outside the province of this article to write their advantages and disadvantages. The government, however, permits the use of the ordinary transit without any solar equipment whatever, provided the surveyor takes frequent observations for meridian, and in the use of the ordinary

transit, the deputy must observe for meridian each night, or upon the sun by day where practicable, turning off transit angles from his meridian for his east and west lines, making the necessary corrections

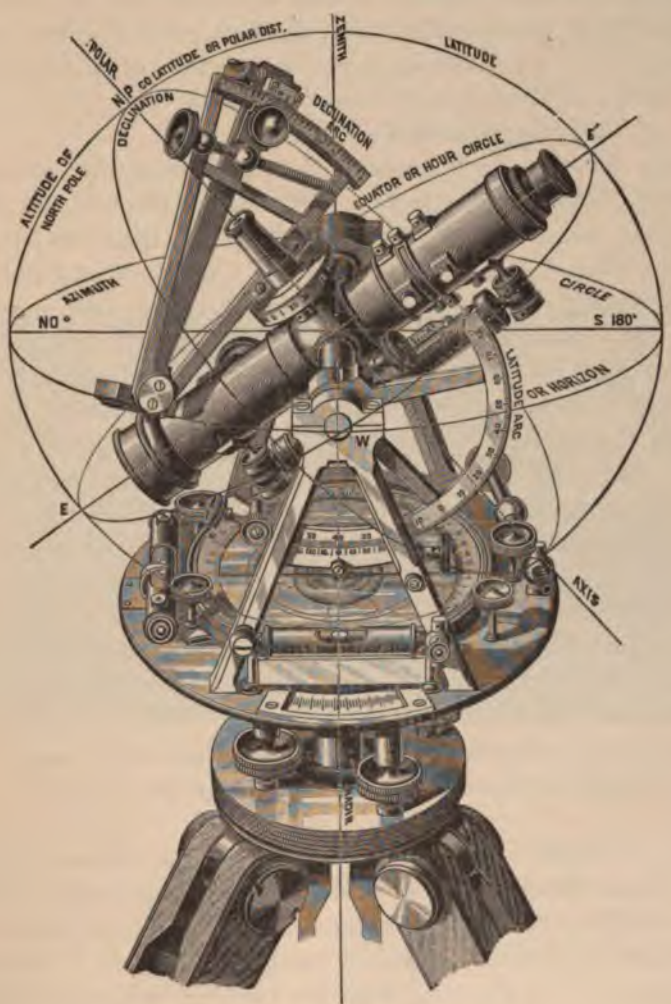


FIG. 4.—A SOLAR TRANSIT.
Showing principles of construction.

and allowances by subsequent observations. Very accurate surveys are made by this method, but the method is not considered by many surveyors to be rapid enough for profitable work.

Meridian Observations.

The work of Government Land Surveys involving true meridian lines makes the ascertainment of the exact direction of a north and south line by the surest and quickest means a great desideratum. The government does not insist upon any one method of finding the stellar meridian, but describes and recommends several methods in the *Manual of Surveying Instructions.*

Among these is the alignment of certain stars when Polaris is in culmination. When the star Zeta of the Great Bear, or the Big Dipper, is in the same vertical plane with the North Star, the latter is on the true meridian. Also when Delta of Cassiopeia and Polaris are in line vertically, a very close approximation to a true meridian is reached. In observing these transits it is necessary to allow a small interval of time to elapse before staking down the meridian.

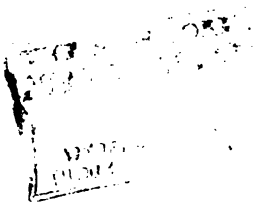
The well known formula for ascertaining the azimuth of Polaris at elongation is furnished to all deputy surveyors, and they are given tables showing culminations of this star. Employment of this means of securing a meridian involves remaining up often until after midnight, and this to the tired deputy means the loss of much needed sleep.

In order to avoid the inconvenience attending the elongation and culmination method of Polaris observations, a plan was devised by the surveying division of the General Land Office, and tables furnished public land surveyors by which the azimuth of Polaris could be ascertained by direct observation of the star *at any hour when visible.* This was a great boon to the surveyor. It is called the hour angle method.

The hour angle is obtained by subtracting the time of upper culmination from the correct local mean time of observation, and applying the result to a table of azimuths of Polaris. Stellar observations for meridian are almost universally used by surveyors, but there are some deputies (those generally who are running lines by transit without solar attachment) who obtain their meridians by observations upon the sun. This can be accomplished by the following rule:

Add together the polar distance, the latitude, and the true altitude; take the difference between the half sum and the polar distance, and note the remainder. Add together the log. secant of the latitude, the log. secant of the altitude, the log. cosine of the half sum,

FIG. 5. — AN INSPECTION PARTY.
The position of the transit indicates the "falling."



and the log. cosine of the remainder; half the sum of these four logarithms will be the log. cosine of half the true azimuth of the sun.

Determination of the true meridian at intervals is required of deputies for the purpose of testing the accuracy of their solar apparatus, especially after moving camp and subjecting the delicate adjustments of the parts to the inevitable jarring and jolting of travel in rough mountainous regions. Conscientious surveyors will observe for meridian nearly every clear evening in order that observations may check each other. Surveyors are required to note in their records the details of such determinations in order that the General Land Office can ascertain if incorrect methods are employed.

Sometimes government surveyors record the details of an hour angle observation, which show an error of azimuth amounting to several minutes. Such an observation was probably never made, for the reason that, if as they state, their solar is in accord with the meridian as determined by such an amount of azimuth, it could not be in adjustment if the azimuth, as *correctly worked out*, were three or four minutes greater or less.

Inspections.

Prior to the "eighties," public land surveys made under contract were seldom examined in the field before payment, and as a consequence, the temptation to fraud and carelessness was very great. In other branches of the government, supplies for official use furnished by contract are duly inspected by vigilant officers to ascertain if the article be according to specification, but in the matter of surveys, strange to say, surveyors were formerly permitted to make returns to the Surveyors General of their work, their oath and that of their assistants being deemed sufficient guarantees of its correctness. But as the country became settled it was apparent that in many instances gross frauds had been perpetrated by unprincipled deputies and the government had paid for mere "paper" surveys; besides in numerous cases inaccurate lines were established, although the monuments were reasonably well marked.

To remedy this, the Surveyors General were instructed to make such inspections as they thought proper by men selected by them and to allow them full equipment of men and supplies to take the field and examine portions of the contract. These inspectors were generally other deputies, and they were naturally loth to find errors in each

other's work. Their reports were usually favorable, and it was rare to have one of these reports show gross neglect of duty on the part of the deputy.

As the work did not seem to grow more in accordance with the required standard, a new departure was determined upon.

A corps of Examiners of Surveys was appointed to consist of experienced engineers and practical surveyors, operating in conjunction with expert public land surveyors detailed from the surveying division of the General Land Office. These examiners comprise a trained class of men who are directed by the Commissioner, and are independent of any local affiliation or sympathy. They report their findings to the Commissioner, and upon their statements he accepts or rejects the surveys. This method has been in vogue for several years and correct and faithfully executed surveys are the result.

Surveys in Newly Acquired Territory.

It will doubtless be asked if the system will be extended to the outlying territories recently added to the United States.

In the case of Alaska, the last Congress extended the system to that district, but not being contiguous to the "States," the lines can not well be prolonged to embrace the lands desired to be surveyed, and if the survey of tracts of agricultural land be applied for by settlers, independent base and meridian lines will probably be established to govern the surveys, as the mountainous character of the surface of Alaska will preclude the possibility of a connected system over the entire country.

In Hawaii the commission appointed to recommend a form of government has advised the appointment of an officer whose functions shall be similar to those of our Surveyors General, to take charge of government surveys of what is known as "crown lands."

In Cuba, Porto Rico, and the Philippines, should there be found considerable areas of crown lands subject to disposal by the United States, the survey of such lands will unquestionably be proceeded with in the same manner as are lands in the public land States.

Reforms.

It would be natural to expect that in the course of years, modifications and improvements of the system would be suggested by experience. One of the changes which may be recommended to Congress

is the use of tubular iron posts, capped with brass, copper, or steel, upon which are to be stamped the data now placed upon the corner stones or posts. These would be more durable and less likely to be removed or destroyed by fire. They would be flanged at bottom and tamped, securing a rigidity not obtainable by the wooden post now in use.

Another change in the law, which is in the interest of promptness and accuracy, is the adoption of a proviso authorizing the contracting for small fragmentary surveys such as islands, for a lump sum. The law provides now that surveys however insignificant, involving sometimes a fraction of a mile, must be paid for at mileage rates, which results in the failure to find competent surveyors who are willing to go to the expense of traveling, oftentimes many miles, to a remote locality and receive three or four dollars as compensation for their work.

Still another progressive step would be the accomplishment of a topographical, or contour, survey simultaneously with the public land survey, such as has been done by the United States Geological Survey. This may be done by increasing the contract rates to cover the cost of topographical survey equipment.

Other and less important changes in the rules for public land surveying have been considered and adopted from time to time by the General Land Office, in cases where no Congressional authority is required. Their enumeration would materially lengthen this article, which is only intended as a brief exposition of the system.

ON THE NECESSITY OF CULTIVATING WATER BACTERIA IN AN ATMOSPHERE SATURATED WITH MOISTURE.

By GEORGE C. WHIPPLE, S. B.

According to present practice the number of bacteria in a sample of water is found by mixing a certain quantity of the water with a certain quantity of sterilized nutrient gelatin and allowing the mixture to solidify in a Petri dish. After a longer or shorter period of incubation at a temperature at or about 20° C., the colonies that have developed upon the gelatin are counted, and from this count the number of bacteria present in the water is determined. Although this method is almost universally used, and although the results obtained are sometimes of the greatest moment, there is such a lack of uniformity in the details of the process as ordinarily conducted, that the determinations of different observers are seldom comparable unless the methods of procedure are fully described. A standard method of procedure is urgently needed, but cannot be secured until the various factors that influence the result have been analyzed and their magnitude determined. In the course of a series of experiments conducted with this object in view, it was observed that the amount of moisture in the atmosphere of the incubator exercised an important influence upon the number of bacteria that developed. The results of these observations are summarized in this paper.

Before the use of the Petri dish it was customary to pour the mixed gelatin and water upon a cold glass plate, where it was allowed to spread out and harden. The plate was then covered with a bell-jar and put in the incubator. In order to prevent the gelatin from drying, moist filter paper was put at the bottom of the bell-jar. Thus the bacteria developed in a moist atmosphere. With the advent of the Petri dish the matter of moisture seems to have been lost sight of. This dish was provided with a tight fitting cover, and this was supposed to prevent evaporation from the gelatin. It is a fact, however, that the Petri dishes now on the market are not tight, and that often the covers

fit the plates very badly. Furthermore, in laboratories where many dishes are in daily use, it is a common thing for dishes and covers to be mismated, and often there is no attempt to mate them. The result is that an appreciable evaporation from the gelatin does take place, and that the amount of evaporation varies with different plates and with different atmospheric conditions.

The effect which this uncontrolled factor exercises upon the development of bacteria is shown by the following experiments. Several series of cultures were submitted to varying conditions of moisture, with other conditions remaining constant. The plates were incubated in a moist chamber, in a closed chamber without moisture, in the incubator (or the ice chest), and in a desiccator. For the moist chamber a desiccator-jar was used, the sulphuric acid being replaced by water. The closed chamber was a desiccator-jar without sulphuric acid or water. The jars were large enough to hold five plates, and in all cases the figures representing the numbers of bacteria found were obtained from the averages of the five counts. The results are given in the following tables. Table I shows the average number of bacteria that developed upon each set of plates. In Table II these figures are reduced to percentages of the number that developed in the moist chamber.

TABLE I.

Series.	Date.	Period of incubation. (Hours.)	Temperature of incubation. (Centigrade.)	Number of Bacteria Per Cubic Centimeter.				
				In moist chamber.	In ice chest.	In incubator.	In closed chamber.	In desiccator.
A.	1899. July 7.	96	16°	583	527	—	—	465
B.	July 7.	96	16°	507	430	—	—	415
C.	July 7.	96	16°	750	683	—	—	618
D.	Oct. 9.	96	15°	450	438	—	395	342
E.	May 20.	72	18°	154	—	115	—	111
F.	Oct. 14.	72	20°	108	—	89	90	84
G.	Oct. 9.	48	20°	423	—	413	354	324
H.	Oct. 17.	72	20°	61	—	59	—	51

TABLE II.

Series.	Date.	Period of incubation. (Hours.)	Temperature of incubation. (Centigrade.)	Per Cent. which Each Number was of the Number Found in the Moist Chamber.				
				In moist chamber.	In ice chest.	In incubator.	In closed chamber.	In desiccator.
A.	1899. July 7.	96	16°	100	90	—	—	79
B.	July 7.	96	16°	100	85	—	—	82
C.	July 7.	96	16°	100	91	—	—	82
D.	Oct. 9.	96	15°	100	98	—	88	79
E.	May 20.	72	18°	100	—	75	—	73
F.	Oct. 14.	72	20°	100	—	82	83	77
G.	Oct. 9.	48	20°	100	—	98	83	77
H.	Oct. 17.	72	20°	100	—	97	—	83
Average.	.....	..	..	100	91	88	85	78

From these tables it will be seen that the largest numbers of bacteria were always obtained from the plates that developed in the moist chamber, and that the smallest numbers were always obtained from the plates that were kept in the desiccator. If the number that developed in the moist atmosphere be assumed to represent the maximum number obtainable by the method, it follows that only 78 per cent. of the bacteria developed in the desiccator, that 85 per cent. developed in the closed chamber, and that the numbers that developed in the ordinary incubator and in the ice chest varied from 75 per cent. to 98 per cent. There was a striking uniformity in the percentages which the numbers in the desiccator were of the numbers in the moist chamber and this was due, no doubt, to the constant atmospheric conditions in the two jars. In the closed chamber also the percentages were quite constant. In the ice chest and in the incubator the percentages were more variable. The atmosphere of the ice chest was ordinarily more moist than that of the incubator, but was seldom saturated on account of ventilation. The amount of moisture in the air of the incubator was generally greater than that of the atmosphere of the laboratory, and varied more or less with the ventilation, the number of plates kept in the incubator, etc. In Series E the relative humidity

of the atmosphere in the incubator was estimated at about 60 per cent. In Series F the humidity was determined by hourly readings of a psychrometer and was found to vary between 65 per cent. and 80 per cent., the average being 75 per cent. In Series G the atmosphere of the incubator was kept moist by means of jars of water, and the average humidity was 95 per cent. In Series H the humidity was similarly kept at 98 per cent. of saturation. The relation between the humidity and the development of bacteria is shown by the following comparison:

Series.	Relative Humidity of the Atmosphere of the Incubator in per cent. of Saturation.	Per cent. which the Number of Bacteria that Developed in the Incubator was of the Number that Developed in the Moist Chamber.
E.	60 (estimated.)	75
F.	75	82
G.	95	98
H.	98	97

The amount of evaporation from gelatin under the conditions described above was determined by weighing the dishes with their contents before and after incubation. It was found that in a saturated atmosphere the evaporation was inappreciable; in the closed chamber it was from 1 to 2 per cent. of the weight of the mixed water and gelatin during 72 hours; in the ice chest it was about 3 per cent.; in the incubator it was from 3 per cent. to 5 per cent.; and in the desiccator it was from 10 per cent. to 15 per cent. The amount of evaporation varied greatly with different plates submitted to the same conditions.

This loss of water by evaporation is sufficient to cause important changes in the composition of the culture media during incubation, and this may be sufficient to affect the development of the bacteria, as these organisms are very susceptible to slight changes in environment. But the chief reason why increased evaporation is accompanied by a decrease in the percentage of bacteria that develop seems to be connected with the supply of oxygen. By successive weighing of the same plates it was found that the rate of evaporation was not constant, but decreased rapidly. For example, during the first hour

of incubation the evaporation from a series of plates proceeded at the rate of .068 gram per hour; after 18 hours the rate of evaporation was .031 gram per hour; after 42 hours it was .012 gram per hour, and after 96 hours it was .002 gram per hour. This retardation of the rate of evaporation appears to be due to a thickening of the gelatin at the surface. If such is the case, the thickened gelatin at the surface might materially reduce the supply of oxygen of the submerged bacteria and prevent the development of the less vigorous aërobic forms. Indeed, it was observed that the plates in the desiccator and in the moist chamber differed more in the number of submerged colonies than in the number of surface colonies.

These facts suggested the possibility that the Petri dish itself might serve to prevent the bacteria from getting a sufficient supply of oxygen. The experiment was made, therefore, of cultivating the bacteria in a Petri dish with the ordinary cover replaced by a ground glass top that made an absolutely air tight joint. A series of five cultivations made in this way gave the number of bacteria in a certain sample as 317 per cc., while a series of cultivations of the same water made in the usual manner gave 413 per cc. In the hermetically sealed dish, therefore, only 77 per cent of the bacteria developed. The air of these dishes was then collected over mercury, and the amount of oxygen determined by absorption with pyrogallic acid. It was found that the air of the ordinary dishes contained approximately 15 per cent. of oxygen, while the air of the sealed dishes contained only 5 per cent. In other words, three-quarters of the original supply of oxygen in the sealed dishes had been used up by the bacteria during 72 hours, while one-quarter of the original supply had been used up in the ordinary dishes. It was found also that the air in the sealed dishes contained 5 per cent. of CO_2, while the air in the ordinary dishes contained but 2 per cent.

As a matter of interest a series of cultures was made in a jar filled with oxygen, and compared with cultures of the same water made in the incubator. It was found that the average number of colonies that developed in the oxygen was 154 per cc., while in the incubator it was 137. The growth in oxygen also took place at a much more rapid rate.

Finally, one important fact was noted in connection with the cultures made in the jars that illustrates the important effect of oxygen. In all the jars the five Petri dishes were piled one on top of the other,

and it was found that almost invariably the plate highest in the jar gave the largest count, and that the lowest plate gave the smallest count. This was particularly striking in the case of the jar filled with oxygen, where the upper plate contained 198 colonies per cc., while the lower plate contained 138. These differences between the upper and lower plates of the jars were greater than the differences observed between plates kept in the incubator. Liquefaction proceeded much more rapidly in the upper plates of the jars. These phenomena seemed to be due to an accumulation of carbon dioxide at the bottom of the jars, where either by its own properties or by exclusion of oxygen, it retarded the growth of the bacteria.

These facts tended to show that the supply of oxygen has a marked effect upon the growth of water bacteria on the gelatin plate, and that whatever tends to reduce the supply of oxygen, whether it be evaporation or an air-tight Petri dish or lack of sufficient ventilation, will tend also to reduce the number of bacteria. The practical inference from this is that in order to obtain the greatest possible development of water bacteria on the gelatin plate, a ventilated dish should be used, and the cultures should be incubated in an atmosphere saturated with moisture.

It has been found that satisfactory ventilation of the Petri dishes may be obtained by grinding several small notches in the edge of the lower plate. If greater ventilation is required, it may be obtained by extending the sides of the lower plate upwards at four points on the circumference so as to form pillars for supporting the cover, thereby allowing a complete circulation of air. It has been found that the bacteria counts obtained by using these ventilated dishes in an atmosphere saturated with moisture, compare closely with those obtained in open dishes protected from contamination and incubated in a saturated atmosphere, the results of one series of comparisons giving 97 and 95 bacteria per cc. respectively, by the two methods. Experiments have shown that there is no danger of these ventilated plates becoming contaminated from the air.

The cultivation of water bacteria in the moist atmosphere has the further advantage that the growths come to maturity in a shorter time. Liquefaction takes place earlier, but the growth of the deep-seated colonies seems to proceed at a still more rapid rate. A greater proportion of the plates are liquefied after 72 hours' growth, but on the other hand, the percentage increase between the 48-hour count and the 72-hour count is much reduced.

Incubators used for the cultivation of water bacteria should be well ventilated, and their atmosphere should be kept at or near the point of saturation. They should be provided with wet and dry bulb thermometers, and the relative humidity should not be allowed to fall below 95 per cent. Experience has shown that an atmosphere practically saturated with moisture may be easily maintained.

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SILICA STANDARDS FOR THE DETERMINATION OF TURBIDITY IN WATER.

By GEORGE C. WHIPPLE, S.B., and DANIEL D. JACKSON, S.B.

The subject of the turbidity of water is one that is growing in importance. This importance varies in different sections of the country. In New England, where the natural waters are comparatively clear, the terms "very slight," "slight," "distinct," and "decided," have been used by analysts to express the amount of suspended matter present. These degrees of turbidity have been estimated by the appearance of the samples to the eye when viewed towards the light. This mode of expression has been discarded by analysts who have had to deal with the problem of turbidity in connection with sand filtration or the mechanical treatment of waters that have large quantities of clay and other foreign matter in suspension. Experiments have shown that it is the finely divided suspended matter in water that is most difficult to remove by any system of purification, and it happens that these same fine particles have the greatest effect on the turbidity of the water. Hence, in questions relating to the filtration of water, the amount of coagulant required for clarification, etc., a reliable expression for the actual turbidity is more serviceable to the engineer than a knowledge of the exact weight of the suspended matter. Consequently indefinite terms have been discarded and more accurate systems of numerical expression have come into use.

Of the various methods that have been suggested, only three have commended themselves to practical use: namely, the Wire Method, the Diaphanometer, and the use of Standards of Comparison. The first is a rapid method for obtaining approximate results, and serves well as a local standard and for the general purposes of field work, but it is not applicable to laboratory use. The second requires a somewhat elaborate apparatus and conditions of observation not readily obtainable in all laboratories. The third method is simple and quite satisfactory for general use. Standards of kaolin have been used for this purpose, but they are open to the objections that they cannot be

readily duplicated and do not keep well when employed in connection with the color standard. These difficulties appear to be overcome by the use of finely powdered diatomaceous earth instead of kaolin. This earth may be obtained in almost any part of the country, and is prepared for use in the following manner:

The diatomaceous earth, as pure as may be obtained, is washed with water to free it from any soluble salts, and ignited to remove the organic matter. The perfectly white earth thus obtained is then treated with warm hydrochloric acid (1 : 1), after which it is washed with distilled water by successive decantations until free from the acid. The material, now composed of practically pure diatom frustules is then ground in an agate mortar to an impalpable powder and again shaken with distilled water. Any coarse particles that may be present are easily separated from the fine particles by sedimentation and decantation. The fine material is then allowed to settle, separated from the water, dried at 100° C., cooled in a desiccator, and placed in a stoppered bottle. The material thus prepared for use consists of particles of silica that are about 1 micron (.001 mm.) in diameter, and that are fairly uniform in size.

A stock mixture is made by adding 0.5 gram of the prepared diatomaceous earth to 500 cc. of distilled water. This is put in a liter bottle in order to give room for violent agitation before measured portions of it are withdrawn. The mixture contains 1 gram of pure silica per liter, or 1,000 parts per million. This is absolutely unacted upon, either by distilled water or by the platinum-cobalt color standard, and when well shaken will always give the same turbidity.

For waters of low turbidities, standards are made up in gallon bottles. The stock mixture above described is called a standard of 1,000. Five standards are made from this by dilution, as follows:

Silica standard.	Number of cubic centimeters of stock mixture, to be made up to 3 liters with distilled water.
0	0
5	15
10	30
15	45
20	60

Nearly all of the natural waters of New England fall below the standard of twenty. These comparatively clear waters may be examined by putting them in gallon bottles like those holding the standards,

and viewing them together towards the light. It is well to have under the bottles a black surface that extends backward for about 1 foot, rising at an angle of about 30°. This enables the observer to distinguish the particles in suspension, to judge the amount of light that they cut out, and to estimate the turbidities even though the particles vary greatly in size.

The numerical expressions given in the following table may be considered as the approximate equivalents of the terms now employed for expressing low turbidities.

Silica standard.	Present system.
0	None.
1 — 2	Very slight.
2 — 5	Slight.
5 — 20	Distinct.
above 20	Decided.

Low turbidities observed in this manner are not appreciably interfered with by the color of the water, and consequently the color standards need not be used in connection with the turbidity standards. But above a turbidity of twenty the water in the gallon bottles is too opaque to make satisfactory comparisons, and it becomes necessary to resort to the use of 100 cc. tubes. (Nessler jars about 20 mm. in diameter and 280 mm. long are preferable for this purpose, but the shorter form of 100 cc. Nessler tubes may be used.) A series of twelve standards is made by diluting the stock mixture to the 100 cc. mark, as follows:

Silica standard.	Number of cubic centimeters of stock mixture, to be made up to 100 cc. with distilled water.
20	2.0
30	3.0
40	4.0
50	5.0
75	7.5
100	10.0
125	12.5
150	15.0
175	17.5
200	20.0
250	25.0
300	30.0

When the turbidities are low, the samples may be compared with the standards by holding both over sharp black lines on white paper, and looking through the tubes lengthwise. They may be compared also by examining them sidewise towards the light or over black lines, thus largely eliminating the effect of color. The higher standards are opaque when viewed lengthwise, and must be examined sidewise towards the light, or over black lines at an angle with the light. During the comparison of the water with the standards, the tubes must be shaken occasionally in order to keep all the material in suspension. The stoppers used in the tubes should be boiled in water before they are used, in order to extract any natural coloring matter which they may contain. Waters that have both a high color and a high turbidity may be compared with standards made by combining the silica standards with the platinum-cobalt color standards. The color of the water is first determined by filtering the sample, and the turbidity then observed by comparing the original water with silica standards made to have the same or nearly the same color.

Various river waters recently examined have shown turbidity-readings up to 3,000 of the silica standard, and some of them have had also a high color. It was found that the turbidity of these waters could be accurately determined by dilution of the samples to bring them within the range of the series above described. In most cases this dilution with distilled water entirely eliminated the effect of color. It is only in cases of especially high color and where great accuracy is required that it will be necessary to use the combined color and turbidity standards. In those cases where the suspended particles themselves are colored, sufficient dilution will overcome the difficulty.

The relative value of silica and kaolin for turbidity standards is shown by the following comparisons: Three samples of kaolin were obtained from different sources and standards made from each by adding equal weights of the material prepared by elutriation, to the same volume of water. The resulting turbidities were far from uniform, as shown by the following comparisons with the silica standard.

	Turbidity.
Silica	100
First sample of kaolin	125
Second sample of kaolin	135
Third sample of kaolin	220

Different preparations of silica from diatomaceous earth on the other hand, gave practically uniform results. Microscopical examination of the silica and kaolins showed that the particles of silica obtained by grinding the diatomaceous earth were quite uniform in size, while the particles of aluminum silicate showed much greater variations. In some of the samples the kaolin particles were much finer than in others, which accounted for the great variations in turbidity in the different samples of kaolin.

The silica method of determining turbidity has been employed with a large number of waters, in which nearly every form of turbidity has been represented, and as a general laboratory method it commends itself for simplicity, uniformity, and accuracy.

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GEOLOGICAL HISTORY OF THE NASHUA VALLEY DURING THE TERTIARY AND QUATERNARY PERIODS.[1]

By W. O. CROSBY.

Introduction.

The Nashua holds a unique place among the rivers of New England, inasmuch as it is the largest stream east of the Hudson and the Champlain Valley, flowing throughout the main part of its course in a northerly direction. Its only real competitors are the distant Hoosac and the neighboring Concord. The Hoosac holds its northward course only for some fifteen miles from its source and is, therefore, relatively insignificant; and the Concord is not only a smaller stream than the Nashua, but it is virtually a river without a well accentuated rock valley, meandering across a drift-covered peneplain from an almost imperceptible southern water-parting, seemingly but little influenced by the geological structure of the region.

The Nashua, on the other hand, flows through a deep and well-defined valley which has been carved out of a great slate formation between the mountainous and semi-mountainous Wachusett-Watatic ridge of granitic and gneissic rocks on the west, and a distinct ridge of granitic rocks and schists on the east. This eastern ridge, though in no sense mountainous, is sufficiently prominent so that it has been credited with climatic influence, protecting the Nashua Valley from the chilling east winds and fogs of the coast. This deep northward draining valley presents ideal conditions for the study of the phenomena of glacial lakes, and probably nowhere in New England was this phase of the closing stage of the Pleistocene ice-sheet more typically

[1] This paper is designed to supplement that on the "Geology of the Wachusett Dam and Wachusett Aqueduct Tunnel of the Metropolitan Water Works in the vicinity of Clinton, Massachusetts," in the *Technology Quarterly* for June, 1899, (Vol. XII, 68–96.) My official connection with the Metropolitan Water Board, as consulting geologist, has afforded me exceptionally favorable opportunities to make this study; and my grateful acknowledgments are again due the Metropolitan Water Board and Mr. F. P. Stearns, the Chief Engineer of the Board, for encouragement in the prosecution of this work and for permission to publish the results of special geological interest. It is also a pleasure to acknowledge the unfailing kindness of Mr. H. A. Miller and Mr. T. F. Richardson, Department Engineers of the Board, and of other members of the Engineering Staff.

developed. One main purpose of this paper is to describe the chief episodes in the history of the glacial lake Nashua. The glacial history of the Nashua Valley undoubtedly affords an explanation of the marked retrograde course of the Nashua River with reference to the Merrimac, north of Ayer, and of the retrograde courses of the principal tributaries of the Nashua itself.

Although, for the reasons indicated, the Nashua Valley presents naturally a very attractive field for the student of glacial geology, it is rendered doubly inviting at the present time by the operations of the Metropolitan Water Board in the construction of the great reservoir required for the proposed addition to the water supply of the Metropolitan District. This reservoir, with an area of six and one-half square miles and a maximum depth of 129 feet, will reproduce in part the glacial lake which once adorned the upper valley of the Nashua, and the preparations for the advent of the former have brought to light some of the more important and significant facts in the history of the latter, and of the Nashua River.

Topography.

Two peneplains are readily recognized in this part of New England. In the order of their development these are: First, the Cretaceous peneplain, with a normal elevation of 1,000 to 1,200 feet in central Massachusetts and gradually increasing in height northward and westward. Since it is from the surface of this peneplain that the mountains of the region, such as Wachusett, Watatic, Monadnock, etc., (erosion-remnants, or monadnocks, of a still more ancient land which was base-levelled in Cretaceous times to form this peneplain) immediately arise, it may also be appropriately designated the sub-mountainous or piedmont peneplain. Second, the Tertiary peneplain, with a normal elevation of 100 to 200 feet, and gradually increasing in height from the shore inland toward the somewhat abrupt margin of the piedmont peneplain, which has been worn away in the development of this lower or coastal peneplain, from the surface of which numerous isolated remnants of the older peneplain now rise as monadnocks, including the Blue Hills, Prospect, Nobscot and Fay Hills, and many others.

The piedmont peneplain is now broadly divided by the Connecticut Valley, the level floor of which is but an inland extension on a belt of

soft rocks (sandstones and shales) of the coastal peneplain. This statement may be repeated for the Merrimac Valley and for its tributary in which we are now specially interested — the Nashua Valley. The coastal peneplain of Eastern Massachusetts is continuous inland with the floor of the Nashua Valley which, as previously noted, has been developed in a band of relatively soft argillaceous strata. The Nashua Valley is, then, a broad and deep trench which has been excavated in the piedmont peneplain adjacent to and parallel with its abrupt eastern margin, in conformity with the geological structure, and contemporaneously with the development of the coastal peneplain, of which its floor is an inland extension.

The drainage of this region is determined by the normal seaward slope of the peneplains, where uninfluenced by the geological structure. The prevailing line of strike in the region of the Nashua Valley is north-northeast, or approximately at right angles to the dominant inclination of the cretaceous or piedmont peneplain; and the Nashua Valley as it now exists, with its floor of argillites and phyllites or semi-metamorphic slates, is due to the fact that the free eastward drainage from the Wachusett-Watatic height of land is intercepted by the band of granitic rocks (granite and diorite) and highly metamorphic sediments (schists, quartzite, and conglomerate) forming the eastern rim of the valley. The Nashua thus, by virtue of the rugged and semi-mountainous topography, shows itself less indifferent to the geological structure of its bed rocks than do most of the streams of southeastern New England.

This view of the geological relations of the Nashua, namely, that the drainage has been controlled by a band of hard rocks, explains not only the close agreement of the trend of the valley and of the main stream with the strike of the rock formations, but also the sharply defined character of the eastern ridge, and the facts that the river follows closely the western base of this ridge, instead of meandering through the middle of its broad valley, that the tributaries are distinctly transgressive, and that all those more than a mile or two in length join the main stream from the west.

The valley of the Nashua is an approximately rectangular depression with a north-northeast trend, excavated in the submountainous peneplain near its eastern edge. The extreme length of the valley, from Stone House Hill in Holden (four miles northwest of Worcester) to the confluence of the Nashua and Merrimac, is about 40 miles;

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but the extreme length of the river, measured from the source of either the North or South Nashua, and omitting meanders, is about 55 miles. The breadth of the valley is approximately uniform and roughly one-third to one-half its length, being 13 miles across the southern end, 14 miles at Clinton, 16 miles at Mt. Wachusett, 17 miles at Pepperell, 16 miles at the State line, and 17 miles at the north end. The extreme breadth, however, is over 20 miles along the line passing through Ayer and Fitchburg, and the total area is about 516 square miles. The axis of the depression (the course of the main stream) as previously noted, lies near the lower eastern margin, giving the valley its highly unsymmetrical cross section.

The Nashua crosses the 400 feet contour at Oakdale; the 300 feet contour at the mouth of Muddy Brook, in Boylston; the 200 feet contour in Groton; and the elevation of the Merrimac at the mouth of the Nashua is about 100 feet. The average fall of the river is thus nearly 10 feet per mile, affording ample water power; and the distribution of the fall is more definitely indicated by the manufacturing towns on its banks. The fall between Oakdale and Boylston is over 100 feet; in the vicinity of Clinton and Lancaster, about 50 feet; at Groton and Pepperell, over 50 feet; and near Nashua, 75 feet. At most points south of Ayer the river lies from 300 to 400 feet below the eastern rim of the valley, or 800 to 1,000 feet or more below the distant western rim. On the 600 feet contour, the valley south of Ayer is only from 3 to 6 miles wide; and the 500 feet contour gives an approximately symmetrical profile, with the river in the middle.

In the glacial history of the Nashua Valley, the depressions or notches of the southern and eastern rims are of special interest. On the southern rim west of the Fitchburg & Worcester Railroad, are notches at elevations, from west to east, of about 1,130 feet (above Asnebumskit Pond), 820 feet (between Asnebumskit and Stone House Hills), 820 feet (between Stone House and Winter Hills), 750 feet (Chaffin Pond and the Boston, Barre & Gardner Railroad), 660 and 650 feet (at the head of Gates Brook, north of Summit Station). The Fitchburg & Worcester Railroad crosses the rim at an elevation of about 540 feet, and one mile farther east is a broad col, cutting the rim to 440 feet, in which head Muddy Brook on the north, and the valley of Lake Quinsigamond on the south. This is the only really important break in the southern rim. Passing to the eastern rim, the first notable depression is that occupied by the Central Massachu-

setts Railroad, two miles south of Clinton, with an elevation of about 360 feet. Two other passes in the immediate vicinity of Clinton, are nearly as low as this (370 to 375 feet). These are the broad pass occupied by the direct road from Clinton to Berlin, in the suburb of Clinton known as the Acre, and that occupied by the New York, New Haven & Hartford Railroad, at Bolton Station. The origin of these low passes, or wind-gaps, in the southern water-parting, or divide, of the Nashua Valley, as well as their glacial history, will be considered in later sections. It is a fact of exceptional importance in the glacial history of the Nashua Valley that no passes even approximately as low as those near Clinton occur in the next ten miles to the northward.

In Ayer the eastern ridge subsides completely and practically disappears, giving the Fitchburg and Stony Brook Railroads free admission to the valley. This broad breach — fully a mile wide on the 300 feet contour, omitting drumlins — of the eastern wall midway of its length and at the point where the valley is widest, is a fact of the first importance, the full significance and interest of which will be developed in a later section. North of this gap the eastern wall does not recover its normal height and continuity. The 400 feet contour encircles a goodly number of isolated hills (largely drumlins), while the 300 feet contour gives an almost continuous barrier as far north as East Pepperell. Further north a few points only reach that height, and the 200 feet contour barely serves to divide the waters of the Nashua and Salmon Brook.

Of the drift deposits of this region, the till, or bowlder clay, is, naturally, chiefly developed upon the higher land, where it is largely massed in the forms of drumlins and drumloid slopes: while the modified drift is confined to the low lands, assuming the form, chiefly, of delta plains corresponding in elevation in each part of the valley to the lowest pass or wind-gap to the southward, each lower depression in the southern and eastern rims of the valley having served in its turn, as they were uncovered during the recession of the ice-sheet, as an outlet of the glacial Lake Nashua, thus conditioning the successive levels of the lake and of its deposits. On the general map of the Nashua Valley (Pl. 1), the special accumulations of till are represented by appropriate conventions, and the modified drift is chiefly confined to the shaded areas. The detailed distribution and special features of the delta plains and their tributary eskers, and the quite

remarkable erosion slopes developed in them during post-glacial time by the Nashua River and its tributaries, will be fully considered in later sections.

The Buried Gorges of the Nashua Valley.

The facts developed by the borings on the site of the Wachusett Dam, as fully described in the first paper (pages 79–85), show that the Nashua here flows over a buried gorge 60 to 70 feet in depth between a precipitous and even overhanging wall of granite on the west, and a sloping wall of metamorphic slate or phyllite on the east. The contact of the granite and phyllite dips to the west 55° to 60°, and this fact has led to the under-cutting of the granite and tended to emphasize the unsymmetrical profile of the gorge. The interesting fact was also brought out by the borings that the bottom of this gorge slopes southward; and it is shown that the distribution of the material (sand, gravel and bowlders) filling the gorge confirms this indication that the gorge was excavated by a southward flowing stream, and hence not by the Nashua which now flows through the valley in the opposite direction, some 70 feet above the bed of the gorge. The head of this preglacial glen is at the Chestnut Street bridge, half a mile north of the site of the Wachusett Dam, where the granite bed rock comes to the surface, and from this head wall, or divide, as stated on page 85, a similar buried gorge probably trends northward.

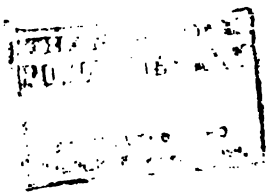
Although the indications afforded by the borings are so plain and unequivocal, they may be regarded as merely confirmatory of the main conclusion that the Nashua is here out of its preglacial course; for that is sufficiently obvious from the contracted and rocky character of this part of its valley as compared with the broad and smooth profiles of the valley to the north and south of Clinton.

On the west, the Wachusett Dam will abut against the precipitous eastern slope of the high ridge of granite, quartzite and phyllite, which is here known as Burdette Hill (530 feet), on which the Clinton reservoir is built. Further north, in Cedar Hill, this ridge bears the higher eastern part of the village of Clinton; and thus for a distance of nearly two miles it divides the Nashua Valley into a narrow eastern portion in which the river flows, and in which the main dam, known as the Wachusett Dam, is being built, and a broad western portion across which is rising the auxiliary dam nearly a mile and two-thirds

in length, known as the North Dike. The topography thus shows very plainly that the ancient channel of the Nashua lies to the westward, beyond Burdette Hill, and the question as to its precise location found a ready answer in the borings on the site of the North Dike.

The North Dike (Pl. 2) is divided, midway of its length, by the subordinate and composite ridge of metamorphic slate, or phyllite, west of Sandy and Coachlace Ponds, and 420 to 430 feet in maximum elevation, on the southern member of which the Catholic cemetery, now soon to be removed, is situated. The subdivision of the main valley by these ridges of granite and schist makes the vicinity of Clinton a highly advantageous site for the construction of the barrier required for the great reservoir. The eastern portion of the dike is to extend from the western slope of Burdette Hill across a level sand plain (Pl. 2), having a normal elevation above low tide of 380 feet, and the valley of Sandy and Coachlace Ponds to the cemetery ridge. West of the cemetery ridge the plain, preserving its normal elevation, is uninterrupted to the high hill at the western end of the dike.

This entire North Dike area, for a length east-west of over one and a half miles, and a breadth of 1,000 to nearly 3,000 feet, has been very thoroughly and systematically examined by wash drill borings, aggregating 1,131 in number, and nearly 18 miles in depth, the extreme depth being about 275 feet. A study of the data afforded by these borings has revealed the probable relief features of the bed-rock surface, as well as the great average thickness of the modified drift and the essential lack of correspondence between the present drift topography and the bed-rock contours, especially for the middle division of the valley between Burdette Hill and the cemetery ridge. Beneath the western division of the valley, beyond the cemetery ridge, the bed-rock surface is an approximate plain sloping southward more rapidly than the plain of modified drift which covers it at elevations above 300 feet, and slightly trenched by several southward-sloping valleys. Passing now to the middle division of the valley, we find that the western slope of Burdette Hill, which is but thinly covered by till, extends for fully 1,000 feet beneath the plain of modified drift with the normal height of 380 feet, to a well defined north-south depression with an average elevation of only about 200 feet, sloping both ways from a distinct water parting. A definite ridge of schist, which is covered at the highest point by 100 feet of modified drift,



separates this depression from the deeper one beyond. Along the west side of the ridge, which is comparable with that on which the cemetery stands, but 150 feet lower, is an uneven bed-rock terrace several hundred feet wide, crossed by several spurs from the ridge, and with an approximate elevation of 190 to 210 feet. Over this terrace, with 120 to 130 feet of drift intervening, lies Coachlace Pond; and immediately beyond, and along a line parallel with the pond and the ridge, the bed-rock surface falls off abruptly about 100 feet more, and the drift reaches the astonishing thickness of 250 to nearly 300 feet.

The lowest elevation of the bed-rock surface determined by the borings is 96.5 feet on the center line of the main cut-off, nearly 200 feet west of Coachlace Pond. Since it is improbable that this boring, which has a depth of 272.5 feet, is located over the very lowest point in this profile of the valley, and especially since it failed to reach bed-rock, we may fairly assume that the minimum elevation of the bottom of the gorge on this line is at least as low as 95 feet, and probably as low as 90 feet. About 150 feet south and 50 feet east of this boring, the drill stopped at an elevation of 101 feet, without reaching bed-rock; but since this is south (up stream) from the first boring it may come quite as near the bed-rock as that. At points 100 to 200 feet west of these borings the drill reached elevations of 111 to 120 feet, and both north and south of this group of borings elevations between 110 and 140 feet were repeatedly reached; but in general, without reliable indications of bed-rock in what appears to be the axis of the gorge, some of the borings reported as reaching bed-rock probably ending either on bowlders or hard-packed gravel. That this depression is a veritable gorge is proved by the abruptness of its slopes at most points, the lateral gradients frequently exceeding 50 per cent. West of the gorge the bed-rock surface rises more abruptly and attains a greater elevation than on the east side. In the north part of the field it crosses the 300 feet contour within 300 to 500 feet of the axis of the gorge. It outcrops repeatedly and reaches an elevation of 424 feet in the cemetery ridge. This eastern member of the complex ridge bears northward and gradually dies out, terminating at an elevation of about 250 feet, some 500 feet north of the point where it passes beneath the surface of the plain. Between it and the similar member immediately west of the cemetery is a lateral rock valley or gorge, represented on the surface by a deep, large and

irregular kettle hole in the drift, and tributary to the main gorge some 600 feet north of Sandy Pond.

No borings have been made in Sandy Pond, which is a large kettle hole with a maximum depth below the water surface of about 66 feet (elevation 334 to 268); but a numerous series has been made, extending from the southwest end of Burdette Hill across the sand plain enclosing Sandy Pond on the east and south to a point about 2,000 feet southwest of the Pond. These borings have clearly located the continuation of the gorge, but have not determined its full depth. As marked on the map, it follows the line of small kettle ponds extending toward Boylston. A well defined branch or lateral gorge extends southeast from Sandy Pond, seeming to connect the main gorge with the present course of the Nashua at the mouth of Cunningham Brook and near the point where the river approaches nearest to the pond, (see the map of the Wachusett Reservoir, (Pl. 2). The granite of the Burdette Hill ridge outcrops just north of this gorge, between Sandy Pond and the river, while beyond the gorge the tapering extremity of this great granite dike reappears between the enclosing schists on Cunningham Brook over 2,000 feet from the river, and the less altered phyllite outcrops through a lobe of the sand plain, midway between the brook and the river on the southeast, and at the extreme southeast corner of the plain, opposite South Clinton Station. As the map shows, two courses for the buried gorge of the Nashua between Boylston and Sandy Pond may be considered. One is direct and conformable with the strike of the strata, while the other is roundabout, and crosses the granite dike, but accords best with the existing topography, following the present course of the Nashua to the mouth of the Cunningham Brook instead of abandoning it at Boylston. These rival courses are represented by dotted lines on the map, as an indication of their hypothetic character. I am, however, strongly disposed to accept the more southern and roundabout course; but the special conditions which seem to demand this choice may be most conveniently reserved for a later section. The reference of the river to the southern course would make of the deep gorge, demonstrated by the borings on the line of the kettle ponds southwest of Sandy Pond, simply the lower preglacial course of Cunningham Brook, which then joined the Nashua at the southern end of Sandy Pond.

At Boylston Village, soon to be a thing of the past, and the former site of Sawyer's Mills, the Nashua now flows over a prominent

ledge of phyllite, which also outcrops near the railroad on the north side of what was formerly the mill pond. These facts show that the river is here out of its preglacial channel, and a general survey of the situation indicates that the ancient channel or gorge lies to the south and not to the north of these obstructions, passing under the northern edge of a high sand plain, which was probably formed by glacial streams in an embayment of the ice-sheet. One important consideration pointing to this conclusion is found in the marked tendency which the Nashua everywhere exhibits to follow closely the southeast side of its valley. Again, the fact that between Cunningham and Muddy Brooks the course of the valley is distinctly oblique to the strike of the highly fissile phyllites gives the spurs projecting into the valley from the north decidedly retrograde, or up-stream, trends, as the map shows; and the ledges in the vicinity of Sawyer's Mills are probably an extension of the cemetery ridge, which is completely buried for more than a mile by the great delta plain of modified drift, and probably deeply notched where crossed by the preglacial channel of Cunningham Brook.

Between Sawyer's Mills and the mouth of Muddy Brook, the buried gorge probably continues along the southeast side of the valley. This is indicated by the ledges of schist in the middle of the valley northwest of Bee's Mills on the southwestward extension of another prominent retrograde spur. The valley turns here through nearly a right angle to a west-northwest course, and this circumstance must have tended to hold the preglacial Nashua against its right hand or southwestern bluff, although the fortuitous distribution of the modified drift has forced the modern stream to the opposite side of the valley. Between Muddy Brook and Oakdale the trend of the valley is approximately at right angles to the strike of the strata, which must tend to make the river more indifferent to the geological structure and the transverse bed-rock profiles of the valley more symmetrical. Hence we may assign the buried gorge a medial position, and the rapid narrowing of the valley in the vicinity of West Boylston makes it impossible that the river should depart widely from its preglacial course; although the ledge on which the dam is built shows that the entire indifference of the modern to the ancient channel still continues, with a strong probability that the latter is, as usual, to the southward, under the steep erosion slope of the high sand plain or terrace. At Oakdale the south branch of the Nashua is formed by the

confluence of the Stillwater and Quinepoxet Rivers, but the valleys of these streams are too narrow and too distinctly V-shaped to permit any wide separation of the ancient and modern channels. We need not doubt, however, that a bed-rock profile would show in every instance a U-shaped gorge at the bottom of the V-shaped valley.

The North Dike borings have definitely located the buried gorge of the Nashua River as far north as the Boston & Maine Railroad (Worcester, Nashua & Portland Division), where it crosses Coachlace Pond. Farther north no deep borings have been made, but that the rock gorge continues in the same general direction can not be doubted; and the outcrops, taken in connection with the general topography, suffice for an approximate determination of its course. Along the line of the railroad, northeast of the point where it crosses the pond, the phyllites outcrop, in part quite prominently, for half a mile, or nearly to the Clinton Station. These ledges are but the high points of a ridge which might be regarded as an extension of the cemetery ridge crossing the North Dike area, and dividing the basin of Coach lace Pond into two troughs. The eastern trough lies between this rocky ridge and the drumloid slopes of till on which the main part of Clinton stands. The axis of this depression, following Coachlace Brook, passes through the lower part of Clinton; and the chief difficulty in regarding this as the preglacial course of the Nashua is the consideration that since the till on the eastern slopes is probably, as the borings and cut-off excavations have proved it to be further south, of only very moderate thickness — 25 feet or less, and almost certainly less than 50 feet — the rock gorge would be improbably narrow, quite certainly not exceeding 300 feet on the 325 feet contour. The only difficulty with the alternative course, which passes under the railroad and the northern division of Coachlace Pond known as Mossy Pond, is that it breaks through the rock ridge supposed to connect the cemetery ridge with the ledges on the railroad instead of following the strike of the beds. But this difficulty vanishes if, as appears on the whole best, we regard the ledges on the railroad as the northern extension of the buried ridge disclosed by the borings on the east side of the deep gorge, this ridge declining or dying out southward, as the cemetery ridge does northward. Assuming, then, that the buried gorge, enclosed by these two ridges, underlies the basin of Mossy Pond, it probably follows further north the course indicated on the map, passing between the large and handsomely glaciated ledge of

metamorphic slate on North Main Street which was laid bare by the bursting of the Mossy Pond dam some twenty years ago, and the ledges among and over which the Nashua now flows in the vicinity of White's Mill in Lancaster. In other words, the ancient and modern channels probably cross near the mouth of Coachlace Brook, the former passing under the sand plain on the northern edge of which Lancaster Commons is situated.

In view of what precedes, we cannot escape the conclusion that the preglacial gorge of the South Nashua diverges from the present course of the river at or below Boylston, that the level of its bed in the vicinity of Coachlace Pond is nearly 200 feet lower than the present surface of the river south of Clinton, and fully 120 feet lower than the bottom of the buried gorge beneath the site of the Wachusett Dam; and it is probable that the latter gorge is the product of a minor preglacial tributary rising near the Lancaster Mills, and flowing south and west around the southern end of the granite ridge, with a total fall of at least 175 feet, to join the main gorge, the probable junction of the two gorges being near the present mouth of Cunningham Brook. In like manner, another minor stream flowed north and west from the Lancaster Mills, with still greater total fall, across the north end of the granite ridge, to join the Nashua near South Lancaster.

During the disappearance of the great ice-sheet from this region, the modified drift, for reasons which need not be specially considered at this point, was deposited in the latitude of Clinton to a greater height in the main valley than in the subordinate eastern valley, thus diverting the drainage and forcing the river through the eastern gorge over a water parting nearly or quite 175 feet high and giving rise to the abundant water power.

In Lancaster the Nashua River proper is formed by the union of its north and south branches, and from this point the river flows placidly through a broad, level, undivided and unobstructed valley, offering no clue to the precise course of the bed-rock gorge for more than eight miles to the line of the Fitchburg Railroad. One and a half miles west of Ayer Junction, where the railroad follows the north side of the river, the river falls over a ledge of slate, producing a small water power; and midway between this point and the junction is a prominent drumloid hill of porphyritic granite. Farther north, along the line of the river, outcrops, to be more particularly noticed later, occur at frequent intervals.

The absence of deep borings in the Nashua Valley north of Clinton deprives us of the definite data requisite to trace the buried gorge of the Nashua in all the lower reaches of its valley. Realizing, however, that a rock gorge whose bottom is less than 100 feet above the sea at Clinton must extend farther seaward than the mouth of the Nashua, I sought for evidence of its existence in the valley of the Merrimac.

Buried Gorge of the Merrimac River at Lowell.

Through the kindness of Mr. W. F. Sullivan, of the Lowell Water Works, I readily obtained data of the highest interest for that part of the Merrimac Valley. The elevation of the Merrimac is about 98 feet above low tide at the mouth of the Nashua, and 92 feet above the same datum above the dam at Lowell, where it falls 35 feet over a very rocky bed. Above the dam, on the north side of the river, between the Pawtucket Boulevard and the river, and at a height of about 5 feet above the river, the city has driven an extensive series of wells into the plain of modified drift. In the first group, about half a mile above the dam, the depths range from 13 to 53 feet. The principal group, embracing 169 wells of an average depth of about 40 feet, stretches along the river between $1\frac{1}{2}$ and 2 miles above the dam. The depths of the deepest of these are given as 73, 80 and 95 feet, the maximum depth occurring at the eastern end of the series. The bottom of this well is near sea-level, and all the deeper wells must be regarded as located in a preglacial buried channel of the Merrimac. The outcrops and shallow borings to bed-rock along the north side of the river from Pawtucketville to Centralville, although leaving something more to be desired, practically bar the way to a gorge large enough for the Merrimac, and 100 feet deep, especially when we consider that the great composite drumlin of Christian Hill, nearly 300 feet high, probably rests on a prominent bed-rock foundation, a continuation of the ledge forming Hunt's Falls, and not in a hole.

South of the river the ledges are planted so thickly, both north and south of the Pawtucket Canal, as to leave no loophole for the ancient river until we reach the valley of River Meadow Brook — a highly suggestive name in this connection — south of Ayer City. Here we find a broad and deep development of modified drift, crossed by the Middlesex Canal at an elevation of 12 feet above the Merrimac;

and both north and south of the canal are extensive plants of driven wells. The figures giving the depths of all the wells indicate, when plotted on the map, a deep rock valley crossing River Meadow Brook near the Framingham & Lowell Railroad. On Chelmsford Street, near Powell Street, bed-rock is 18 feet below the surface, and near the corner of Chelmsford and Forrest Streets what is supposed to be bed-rock, though probably a bowlder, was struck at a depth of 10 feet. But 1,000 feet to the northeast, near where Plain Street crosses River Meadow Brook, bed-rock was reached at 83 feet, or about 73 feet below the level of the Merrimac, and 19 feet above low tide. These data seem to locate the north side of the lost valley as passing beneath Ayer City. Farther south, at points on both sides of the railroad, borings 75 and 78 feet deep failed to reach bed-rock. That this depression is continued westward toward the Merrimac is indicated by an old well 53 feet deep, west of Chelmsford Street, in the gently sloping sandy valley of Black Brook. Following this course to the river, and keeping to the west of the rock outcrop at Middlesex Station, brings us opposite the deep wells on the north bank. The evidence is still incomplete, but it seems probable that a preglacial gorge of the Merrimac crosses the present course of the river at the point indicated, and passes south of Lowell through the valleys of Black Brook and River Meadow Brook. Beyond River Meadow Brook I have been able to obtain no significant data from borings or wells, but the surface features are not wholly devoid of interest in this connection. The ledges in River Meadow Brook near Gorham Street, and in the Concord River in the last mile of its course, during which it falls 40 feet, as well as the ledges at Hunt's Falls (9 feet) above Duck Islands, indicate plainly enough that the preglacial Merrimac did not follow that course. Eastward from the deep borings in the valley of River Meadow Brook is a level sand plain stretching to the Concord and beyond. Above the upper or Wamesit Falls on the Concord, the way appears clear for the buried valley until we reach the ledges on either side of the Boston & Lowell Railroad near the west bank of the river. This affords an apparent gap of 3,000 feet on the 100 feet contour. Farther eastward, toward Trull Brook, the available space is more restricted, being reduced nearly to 1,500 feet on the 140 feet contour between the ledges southeast of the Fort Hill drumlin. From this point the valley of Trull Brook affords, so far as can be judged from surface features, an easy and natural course for the buried gorge. It

is bordered by ledges and modified drift on the west, and by till on the east; and the gorge, if it exists here, is probably filled in this instance by till. This course by Trull Brook appears on the whole more satisfactory than the course from the head of Trull Brook northwest to the Merrimac below Hunt's Falls. Whatever course it may follow east of Fort Hill, it appears at least possible that the gorge of the preglacial Merrimac passes south of Lowell and under the Concord River, which was, according to this view, about a mile and a half shorter in preglacial times than now. The only alternative hypothesis worthy of consideration, viz., that the buried gorge of the Merrimac passes from 1 to 2 miles north of Lowell, from the vicinity of Tyng's Pond to either the gap between Christian and Loon Hills, or to some point near the mouth of Bartlett Brook in Methuen, is, possibly, more probable. It has the advantage of giving the Merrimac a more direct course to the sea. According to this view, the deep borings west of Lowell would represent the preglacial gorge of Stony Brook, now tributary to the Merrimac at North Chelmsford, and the deep borings south of Lowell might then be referred to the ancient channels of Concord River and River Meadow Brook. The present valley of the Merrimac below the Pawtucket Fall was occupied in preglacial times only by Beaver Brook.

The foregoing attempt to trace the ancient channel of the Merrimac around Lowell, is based upon the assumption that the Merrimac followed in preglacial times its present course from Lowell to the sea. Farther study has convinced me, however, that the preglacial Merrimac was tributary to Boston Harbor; and in this direction, southeastward from River Meadow Brook, we readily find a direct and unobstructed course for its buried gorge, as will be more fully pointed out in a later section.

We cannot, of course, suppose that these facts are unique, but they must be typical of the entire region. And it is interesting to reflect that the removal of the mantle of drift which now smothers and blots out the preglacial topography of southeastern New England, would reveal completely and deeply intrenched drainage systems — a peneplain traversed, in every direction and at frequent intervals, by deep, narrow, and intricate gorges, or, in other words, a youthful topography of far more rugged, picturesque, and difficult aspect than that which the ice-sheet has left us.

Pleistocene Changes in the Course of the Nashua River and the Composite Character of its Modern Channel.

The retrograde course of the lower Nashua with reference to the Merrimac, and of the principal tributaries of the Nashua with reference to the main stream, were referred to in the introduction as one of the special problems which a study of this river system presents. We come now to a more particular consideration of this feature. In a broader view of the problem we see not merely that the streams have retrograde courses, but that there is a very decided convergence of the drainage of the main part of the Nashua Valley toward the great break in the eastern rim of the valley at Ayer Junction. This break is so profound that the water parting between the Nashua River and Stony Brook becomes almost imperceptible, and appears to be composed wholly of drift. These facts naturally suggest an outlet for the drainage of the Nashua Valley in this direction; and this hypothesis is so attractive that I have tested it by a careful examination of the valley of Stony Brook from Ayer to the Merrimac at North Chelmsford. For the entire distance, from the Nashua south of Ayer Junction to North Chelmsford, we have a broad, open, and unobstructed valley, entirely out of proportion to the small stream which now occupies it. With one exception, within a few rods of the mouth of the brook at North Chelmsford, the valley is virtually devoid of rock outcrops, indicating a great average thickness of the drift. The valley is not only broad, but the breadth is remarkably uniform, so that it is practically a valley without a head, a mere strait some dozen miles in length between the Nashua and Merrimac valleys, and not at all the type of valley we should expect if it were due to the unaided activity of Stony Brook. Assuming an approximately uniform gradient for the buried gorge of the Nashua from Clinton (95 feet) to the Merrimac (sea level), via the valley of Stony Brook, the bed of the gorge should be 50 or 60 feet above sea level, in the vicinity of Ayer. Hence the depth of its burial probably diminishes from nearly 200 feet east of Ayer to about 100 feet at North Chelmsford. So far as can be judged from the surface indications, the gorge probably follows very closely the present course of Stony Brook, except at its junction with the Merrimac, where it probably turns slightly to the south to avoid the ledges of granite. The valley presents a continuous floor of modified drift, bordered on either side, except near its mouth, by till.

It appears, then, that the valley of Stony Brook offers no facts inconsistent with the view that it afforded, in preglacial times, an outlet for the drainage of the Nashua Valley; and that as a normal accident of the drift deposition, the valley was sufficiently obstructed, east of Ayer Junction, to turn the drainage northward across the low water-parting at East Pepperell. In corroboration of this view, we have not only the important fact that the drainage of almost the entire valley naturally converges upon Ayer, the probable preglacial confluence of the streams being shown by the broken lines on the map (Pl. 1), but the further fact that north of Ayer the present valley of the river becomes relatively narrow and more obstructed by ledges. The ledges west of Ayer Junction have been noted. About two miles northwest of the Junction are prominent slate ledges in the river, which probably represent a low place in an original water-parting between Mulpus Brook and the Squannacook River. At East Pepperell the indications are very plain that a continuous rocky ridge, having a general north-northwest and south-southeast course, separated the waters of the Nissitissit River from a small and rapid stream flowing northward to the Merrimac at Nashua. When the normal eastward drainage of the Nashua Valley was obstructed, this little stream, with a watershed equal to about six per cent. of that of the Nashua, suddenly fell heir to all the waters of its great rival, and Westford and Chelmsford lost the power, and consequent prosperity, which we now find at Nashua. If this be the true history of the Nashua, the main stream is distinctly composite, the flow has been reversed for the middle link, and it owes its distinction as a northward-flowing stream to an accident of its glacial history, the normal trend of the drainage being eastward from the common focussing point at Ayer.

In my opinion, a precisely similar case is presented by Salmon Brook, which so closely parallels the Nashua on the east. It rises in Groton within a mile of Stony Brook, and flows northward in a nearly direct line, fully 16 miles, to join the Merrimac at Nashua, hardly more than a mile from the mouth of the Nashua. It is clearly another triple composite, made up of a tributary of Stony Brook, a tributary of the Merrimac through Dunstable and Tyngsborough, and an original tributary of the Merrimac at Nashua.

The reopening of the Stony Brook outlet for the Nashua drainage, would make the courses of all the principal tributaries direct, with the exception of the North Nashua; but this important branch would

still appear hopelessly retrograde. Its course is essentially direct from its sources to North Leominster; but instead of turning southward here, running counter to the main stream, and reaching the common meeting-point after a journey of over 16 miles, it ought to continue eastward via Shirley Reservoir and village, reaching the goal in 7 or 8 miles. Between the North Nashua and Shirley Reservoir is a remarkable assemblage of drumlins, including both simple and highly composite forms. To trace a buried gorge across such an area, with any degree of certainty, is not a simple problem; but it happens, in this instance, that the most direct course is the one which would naturally be chosen on other grounds, since it offers the lowest barrier and is free of ledges. It passes first northeast and then east from North Leominster Station across a divide, some 70 feet in height above the river, and consisting, apparently, wholly of unmodified drift. A careful examination of this route discloses no more serious obstacle; and I believe that in preglacial times the North Nashua was, in its entire course from its source to the Merrimac, the most direct and most central member of the Nashua system, and in these respects best entitled to rank as the main stream.

South of North Leominster the present valley of the North Nashua is rock-bordered and narrow, and before reaching the mouth of Wekepeke Brook, it falls over two dams built on rocky ledges, apparently crossing a water-parting here. At the extreme north end of Ballard Hill, where the river turns from an east-west to a nearly due north-south course, is another dam on a bed-rock foundation. Below this dam the valley is again contracted, and a mile to the southward brings us to another dam, but with no ledge in sight. North and east of this great bend of the North Nashua is a high sand plain, but a marked north-northeasterly depression across it, along a line of ponds, suggests a preglacial outlet for Wekepeke Brook and its tributaries in this direction, as indicated on the map; while another small stream flowed south-southeast, from the last dam mentioned, to the South Nashua, in Lancaster.

On comparing these various instances of diverted drainage with reference to the nature of the obstruction, it becomes apparent that the modified drift has played a much more important part in this rôle than the till. The till, with the exception of the drumlins, was distributed with approximate uniformity on the melting of the ice; but rather more abundantly, as a rule, on the highlands than in the val-

leys; and since the drumlins were planted chiefly on moderately elevated rocky tracts, they have interfered but little with the courses of the streams. Assuming that the North Nashua once flowed eastward through the valley of Shirley Reservoir, then we have in North Leominster the most important instance in the entire Nashua region, of the obstructive agency of drumlins, and here the east-west course of the stream gave the ice an exceptional opportunity to scrape its gorge full of bowlder clay. The ice movement was most persistent and efficient in the north-south valleys, and tended to keep them clear of débris; when the ice became stagnant and slowly wasted by melting, it naturally lingered longest in these deep and narrow gorges. Hence, as the borings at Clinton so abundantly show, they are filled chiefly with modified drift deposited by the impounded waters.

Tertiary Changes in the Courses of the Nashua River and its Tributaries.

Important as were the changes in the drainage of this region during its glacial history, and due chiefly to the accidents of drift deposition, it appears probable that the changes of preglacial or Tertiary time, during the development of the coastal peneplain, were still more momentous. In fact, it may be doubted if many rivers have had in this respect a more remarkable history than the Nashua, or are now of a more highly composite character. The evidence of a considerable rearrangement of the drainage lines on the eastern slope of the Wachusett-Watatic ridge during Tertiary time, is found in some otherwise unexplained retrograde courses of the Nashua system, and especially in the deep notches or wind-gaps of the southeastern rim or water-parting of the Nashua Valley.

At the time of its elevation the Cretaceous peneplain was probably covered, at least as far inland as the Nashua Valley, by a mantle of Cretaceous sediments, and across this uplifted deposition plain the rivers probably found their way seaward in utter disregard of the structure of the hard rocks beneath, until, through the gradual disappearance of the still recent and essentially unlithified deposits they were superimposed upon the old erosion plain, or peneplain. This view, which is on *a priori* ground extremely probable, obviates the necessity of going back to pre-Cretaceous time for an explanation of the courses of the drainage at the beginning of the Tertiary cycle, and

affords an independent warrant for the assumption that the drainage, influenced only by the general uplift, was, in general, directly seaward and essentially non-sympathetic with reference to the structure of the peneplain. We thus find a ready explanation of the fact that existing or past drainage channels sometimes lie across the hardest rocks of the region, as where the preglacial main stem of the Nashua system, now the valley of Stony Brook, crosses the Westford area of granite for a dozen miles, from Ayer to the Merrimac, in close proximity to a belt of relatively yielding mica schist. It is not improbable, however, that on the Cretaceous peneplain, nearly a thousand feet above the present surface, the mica schist may have covered the granite.

We may safely assume that one main line of drainage at the beginning of the Tertiary cycle extended, as previously stated, from the sources of the North Nashua above Fitchburg in an easterly direction across the successive belts of gneiss, schist, argillite and granite to the Merrimac at North Chelmsford, the principal tributaries being the Nissitissit and Squannacook Rivers on the north, and on the south Wekepeke Brook, and a still smaller stream in what is now the main valley of the Nashua.

Two other, quite independent but long-since extinct main lines of drainage across the Cretaceous peneplain for the waters of what is now the Nashua Valley, are, I believe, indicated by the marked depressions or wind-gaps in the vicinity of Clinton and at the head of Muddy Brook in Boylston. These gaps are the more remarkable, and special explanations of their origin appear to be the more urgently demanded, since they do not represent exceptionally weak points in the geological structure; but, on the contrary, have been cut out of the most resistant rocks of the region, including the porphyritic and muscovite granites, diorite and quartzite.

The broad gap between Muddy Brook and the valley of Lake Quinsigamond, over half a mile wide, and, disregarding the drift, probably not much over 400 feet above the sea, with elevations of 700 feet on either side, is in the direct line of Stillwater River. The courses of the main tributaries of the Quinepoxet River — Trout Brook, South Wachusett Brook, etc. — suggest an independent outlet through the much higher (760 feet) gap occupied by Chaffin Pond. These two lines of drainage from the southern slope of Mt. Wachusett, converging south of Worcester, and tributary to Narragansett Bay, were later, but at an early period, merged in one nearer their sources by

the cutting through of the ridge southwest of Oakdale represented by Malden Hill, by the backward cutting of a tributary of Stillwater River. The points deserving special emphasis are: (1) that the Muddy Brook and Lake Quinsigamond pass is in the direct course of Stillwater River in its normal outflow from the Wachusett height of land, this drainage being distinctly retrograde with reference to the main line of the Nashua; and (2) that this broad and deep notch in the rim of the Nashua Valley, and the ample valleys leading up to it on either side, are entirely disproportionate to the insignificant rivulets which now pose as their architects. The utter inadequacy of these tiny brooks to the erosion of this great valley becomes still more obvious when we observe the slight fall on the south side, between the pass and Lake Quinsigamond, not exceeding the normal or average fall of the main line of the Nashua River. In short, this is a very clear and normal example of a beheaded valley, the Nashua River, by efficient backward cutting on relatively soft rocks, having captured at one stroke the entire Stillwater-Quinepoxet system.

Of the three low passes in the vicinity of Clinton, the most southerly, now occupied by the Central Massachusetts Railroad, and soon to be closed by the building of the South Dike, is the lowest, and, in this connection, the most important although they are closely united in origin, representing converging lines of drainage, branches of one ancient river. The elevations, as previously stated, range from 360 to 375 feet, or, disregarding the drift, from 340 (South Dike pass) to 375 feet, the elevations of the two northern and higher passes being approximately equal. The Muddy Brook-Quinsigamond pass marks the extreme southern angle of the Nashua Valley, where the drainage now turns through more than a right angle to the normal north-northeast course. On the other hand, the Clinton passes, which may be regarded in the general view as one, are, as previously noted, the deepest and only important notches in the eastern rim of the Nashua Valley south of Ayer; and, like the notch at Ayer, they represent a former focussing point of an independent but relatively unimportant west-to-east drainage system.

This system appears to have gathered water from the lower but not from the upper slope of the Wachusett ridge; unless we assume, as we may with a fair degree of probability, that the valley of the Washaccum Ponds and Cunningham Brook is an ancient alternative course of Stillwater River; or that the diversion of the Stillwater

from the Quinsigamond Valley was accomplished by this eastward-flowing stream and not by the comparatively modern Nashua. That one or the other, or both, of these views is true is most probable. The latter is specially favored by the fact that this eastward-flowing stream, which we will call Wachusett River, crosses the granitic ridge at a point three miles east of the Muddy Brook-Quinsigamond pass, where the ridge is from 100 to 200 feet lower, the actual difference in level of the two passes being nearly 100 feet. The rapid fall thus insured Wachusett River was sufficient to give even a small stream considerable erosive power and enable its southern tributary to cut back through the soft argillites until it tapped and diverted the Stillwater.

The pass at Bolton Station, northeast of Clinton, is in the direct line of the north branch of the Nashua River, below its great bend at the north end of Ballard Hill. The North Nashua, as we have seen, is probably a highly composite stream, the drainage of the upper section of its valley in preglacial times having been, as I suppose, directly eastward from Fitchburg to Ayer, as the main stem of the Nashua system, while the middle section, between North Leominster and Ballard Hill, was tributary northward through Wekepeke Brook to the main stem in Shirley, and only the lower section, in Lancaster, had a distinctly retrograde course. It was this relatively small stream, rising in the north part of Lancaster, and receiving a northeastern tributary in South Lancaster, that in early Tertiary times continued in its south-southeastern course, crossing the eastern ridge on the porphyritic granite at Bolton Station and flowing down the valley of North Brook to join, at West Berlin, the main branch of Wachusett River, which may have passed from the South Dike pass either north or south, but probably south, of Snake Hill. A third branch of Wachusett River probably had its source in Sterling and, converging upon Clinton, crossed the site of the village, formed the col between Cedar and Burdette Hills, crossed the eastern ridge by the middle pass, at the Acre, and thence by a natural and direct valley joined the main stream at West Berlin, which was thus the common meeting point for the Wachusett system. From West Berlin the broad valley of North Brook slopes gently southeastward across the Tertiary peneplain to join the valley of the Assabet in South Berlin; and the waters of Wachusett River, we may suppose, reached the sea, as do the waters of its shrunken trunk — North Brook, via the Assabet, Concord and

Merrimac Rivers; although an east-southeastern course to the valley of the Charles is, perhaps, more probable.

After the diversion of Stillwater River from the Quinsigamond Valley to form the main branch of Wachusett River, the drainage of what is now the Nashua watershed, with the exception of the extreme northeast corner, was accomplished by two eastward-flowing rivers — the Nashua and the Wachusett, the former crossing the granitic ridge now forming the eastern wall of the valley at Ayer, and the latter in the vicinity of Clinton. From their respective passes to the relatively low level of the Merrimac at North Chelmsford and Lowell was about a dozen miles for the Nashua and more than three times that distance for the Wachusett. The advantage of a more rapid fall enabled the Nashua to outstrip its southern rival in the work of cutting back its channel through the granite ridge and developing its system in the broad band of relatively weak argillites. The original divide between the two systems probably extended from Prospect Hill in Harvard, where the valley is still narrow, to the north end of Ballard Hill in Lancaster. The more aggressive Nashua gradually cut back this divide until it appropriated the water of the northern branch of Wachusett River, leaving the pass at Bolton Station dry. Later, the middle branch shared the same fate, and the pass at the Acre was abandoned. Each captive stream became at once, by virtue of its increased fall and power, an energetic captor; and thus the insignificant middle branch of the Wachusett, cutting back across the area of Coachlace and Sandy Ponds, absorbed first the water of Cunningham Brook; and then, with this reinforcement, it cut either southeastward across the granite ridge which was still covered by the phyllites, or southward toward Boylston, until it tapped and drew off the Stillwater branch or main stream of the Wachusett system, and the victory was complete. The narrow and more or less obstructed parts of the valley, as at Still River, Clinton, and Sawyer's Mills in Boylston, mark the positions of the divides which were pierced during this process of fluvial federation. The failure of the Nashua to make like acquisitions to the northward and thus preserve the original symmetry of its system, is due to a variety of causes, such as the greater hardness of the rock formations in that direction, the less rapid fall and the proximity on the east of the deep valley of the Merrimac.

After the close of this period of territorial expansion, the river continued to widen and deepen its valley, until in the late Tertiary

time the lower courses had been approximately graded for a breadth of from one to several miles. But at this stage the development of the Tertiary peneplain was arrested by the strong elevation of the land in early Pleistocene time which ushered in the great ice age. This rejuvenation of the streams (in volume, possibly, as well as in gradient or slope) naturally led to a rapid deepening of their channels and the development of the system of deep U-shaped gorges revealed by the borings. When the ice-sheet disappeared, these gorges were left full to the brim of drift, chiefly modified; and as the result of late glacial and post-glacial oscillations of the land, the Tertiary peneplain now stands, in this part of New England, from 100 to 200 feet above the sea.

Taking a broader view of the drainage of Eastern Massachusetts, attention is attracted to the course of the Merrimac below its great bend at North Chelmsford. When the Cretaceous peneplain was recently uplifted, and the streams were finding their way seaward across its sedimentary cover — the young coastal or deposition plain — it is probable that the Merrimac, uninfluenced by the structure of the hard rocks beneath, continued in its normal southeastward course until it became tributary to Boston Harbor, following the line of the Boston & Lowell Railroad and Middlesex Canal to the valley of Mystic River. This route, which now barely rises above the 100 feet contour, lies, between the Merrimac above Lowell and Woburn, across a nearly level plain of modified drift several miles wide, remarkably free from rock outcrops, and bordered on the northeast and southwest by land from 50 to 200 feet higher. In other words, it may be regarded as a wide and probably a deep valley filled to the brim with glacial sand and gravel, and merging imperceptibly with the valley of the Mystic, which has no proper head, and is in size quite out of proportion to the diminutive stream, miscalled a river, which courses sluggishly through it. This broad and direct valley is in striking contrast with the narrow, crooked, and much longer valley of the modern Merrimac between Lowell and the sea.

It might be supposed that the Merrimac was diverted from its southeastern course during Tertiary time by the backward cutting on a band of relatively weak rocks (the Merrimac slates) of a small stream following the present course of the Merrimac below Lowell. But it is quite as probable that the Merrimac held to the more direct and shorter southeastern course until the advent of the ice-sheet, which

left sufficient drift in its valley to turn it over a low divide at Lowell into the valley of this northeastward flowing stream. This view explains why the deep buried gorge of the Merrimac can not be satisfactorily traced around the southeast side of Lowell, from River Meadow Brook to Trull Brook. From River Meadow Brook it probably follows approximately the line of the Middlesex Canal to Boston Harbor. As I have elsewhere pointed out, the Merrimac probably continued to hold to this line during the recession of the ice-sheet, while the ice still occupied what is now the valley of the Merrimac northeast of Lowell, the shallow glacial lake thus resulting accounting for the broad development of modified drift southeast of Lowell.

The Concord River, according to this view, probably joined the Merrimac in preglacial times in North Billerica; and the southeastern course here assigned the Merrimac increases the probability that the course of the ancient Wachusett River was also southeasterly from West Berlin to the valley of the Charles and Boston Harbor, appropriating on the way the headwaters of what are now the Assabet and Sudbury Rivers.

In closing this section we may note the interesting fact that the general result of the rearrangements of the drainage discussed in this paper, whether due to the fluvial competition of Tertiary time, or the accidents of drift deposition, has been to bring the streams more and more into harmony with the geological structure, so that, in spite of the drift, the adjustment is well nigh complete, at least for the main lines.

Lake Nashua.

The Quinepoxet and Boylston Stages.

The history of Lake Nashua commenced when the retreating margin of the great ice-sheet first began to uncover the southern water-parting of the Nashua Valley. The southern end of the valley is divided by the north-south ridge terminating in Malden Hill, south of Oakdale. The minimum elevation of this ridge, just south of Malden Hill, is about 770 feet. West of the ridge, on either side of Stone House Hill, are two passes across the water-parting at about the same height — 820 to 830 feet. But the only pass that need be specially noted is that occupied by Chaffin Pond and the Boston, Barre & Gardner Railroad, with a height of 760 feet. As long as the ice

retained its hold on Malden Hill this pass, discharging southward into North Pond and Blackstone River, must have afforded the principal outlet for the impounded waters of the Quinepoxet Valley; and it is proposed to designate this the Quinepoxet stage of Lake Nashua, with a normal level of about 760 feet. It affords a ready explanation of the most of the modified drift observed in the Quinepoxet Valley above Oakdale.

East of the Malden Hill ridge we find passes at heights of 660 and 560 feet, the latter being occupied by the Fitchburg & Worcester Railroad. But these must have been short-lived as water courses, because immediately to the eastward, as previously noted, is the broad pass between Muddy Brook and Lake Quinsigamond, only 460 feet or less in height. The portion of the lake tributary to this most important of the southern outlets, the ancient and heheaded channel of Stillwater River, lies chiefly in the towns of Boylston and West Boylston, and may be appropriately known as the Boylston stage. When the ice filled this valley, but had disappeared from the bordering ridges, embayments in the body of the ice, connected by marginal streams must have been a characteristic feature, giving rise to marginal deposits of modified drift, and explaining the fact that the deposits of this stage rise to somewhat greater heights than the outlet. The same agency, coöperating apparently with a powerful subglacial stream, spread extensive deposits of modified drift in the Quinsigamond Valley sloping southward from this outlet; and in the outlet itself, nearly a mile in extreme width, the undulating and kame-like character of the deposits of sand and gravel testify to strong and variable currents. The opening of the Boylston outlet involved a change of level of about 300 feet, and consequently, such a complete abandonment of the Quinepoxet area that the two parts or stages of the lake nowhere overlap, but appear on the map as entirely distinct and separate bodies of water. It is probable, however, that they were in part contemporaneous lakes at different levels, Quinepoxet Lake continuing until the ice relaxed its hold on Malden Hill.

It is probable that toward the end of the flow through the Boylston outlet, when the water was beginning to find an outlet elsewhere, this outlet became somewhat clogged up and thus raised above its normal height, and the seasonal variations in the volume of water must have caused changes of level, so that it is not surprising that the delta as well as the marginal deposits of this stage vary somewhat in height.

The Boylston stage clearly occupied the valleys of Stillwater River and the Washaccum Ponds, agreeing with the Quinepoxet stage in having its major diameter transverse to the axis of the valley. This is, also, but one of many indications that the ice front held in general a northwest and southeast direction. The contour lines on the Worcester and Marlboro sheets of the topographic map show with approximate accuracy what is left of the special delta and terrace plains of modified drift, ranging in elevation from 440 to 460 feet, formed during this stage. Naturally enough these short lived lakes did not build normal deltas over their entire areas; but we must, in this connection, make liberal allowance for the postglacial erosive action of the river. Commencing on the west, we find a small but normal development of this plain rising abruptly above the village of Oakdale. South of Quinepoxet River it is continued along the south side of the valley as a broad level terrace, with an abrupt erosion slope facing the river to Boylston Common, where it is very perfectly developed, and is marked by several kettles. The plain broadens here to half a mile, but is less perfect in surface, appearing to consist of a thin deposit of modified drift over till. South of the high quartzite hill rising boldly from the inner margin of the valley west of Muddy Brook, the modified drift has a strong development, with undulating contours, and several large and deep kettles along the eastern margin of the plain. The complex of eskers and kames in the Muddy Brook-Quinsigamond outlet has been noted. Along the line of the Fitchburg & Worcester Railroad the modified drift rises, as previously noted, about 100 feet above the normal level of the Boylston stage, and has an important development in the pass 560 feet in height occupied by the railroad, sloping gently southward from the pass in a broad apron plain. This is clearly a record of the time when the ice still filled the Muddy Brook-Quinsigamond outlet, and an important marginal stream, embracing, possibly, the whole of the Quinepoxet and Stillwater drainage, escaped from the valley at this higher level. Incidentally, we have here, also, evidence of the general northwest-southeast trend of the margin of the waning ice-sheet. Along the east side of the Muddy Brook Valley the Boylston plain is distinctly developed, and is especially perfect toward the north, where it rises in a very steep erosion slope from the river and Dover Pond; and again, southeast of Sawyer's Mills, an unmistakable erosion scarp rises from the mill pond (now drained) to a plane of the normal height

fully half a mile square, and extending southward half way to Boylston Center and eastward nearly to the South Dike pass. East of the mill pond the erosion scarp is transferred to the Clinton (370 feet) plain; and the Boylston plain, rising 70 feet above the Clinton plain, presents to the northward a normal ice margin, with a series of eskers which, apparently, mark the courses of streams tributary to these high deltas. Immediately east of South Clinton Station, the Clinton plain is crossed by two eskers from 400 to 500 feet apart and trending in a south-southwest direction. The western esker, which here barely reaches the level of the Wachusett Reservoir (395 feet), bears to the southwest, and, crossing the road to Boylston Center about one-fourth of a mile from the station, is represented by the two north-south islands in the reservoir on the west side of the road (437 and 422 feet). As it approaches the irregular northern or ice margin of the Boylston plain, the esker turns quite abruptly to a general westerly course, and forming one large island in the reservoir, continues as a more or less discontinuous, serpentine ridge, parallel with the high slope, to Sawyer's Mills, where it turns to the southwest as if seeking the Boylston outlet at the head of Muddy Brook. The course of this glacial stream is marked also by a series of deep kettles. The eastern esker near South Clinton Station forms a small island (400 feet) in the reservoir and continues in a general southerly direction up the east side of the valley of a small brook (a bay of the reservoir) with a slight interruption, across the new road to Boylston Center, toward the low place (480 feet) in the water-parting about a mile south-southwest from the South Dike outlet. As we approach this outlet, the modified drift which can be referred to the Boylston stage of Lake Nashua becomes more and more uneven, patchy, and esker-like, but does not wholly cease until the outlet is reached.

That these high level deposits of modified drift were, in the main, formed in standing water, and only to a limited extent by marginal streams, is indicated by the considerable breadth of the plains at some points, and also by the more or less distinct depression which usually, especially east of Muddy Brook, separates the sand plains from the slopes of ledge and till rising above them on the southeast. This depression or channel is the normal product of the water flowing over the surface of the delta, where the growing edge of the latter approaches the limit of the basin. The water must then maintain a passage to the right or left, parallel with the front of the delta.

It is an interesting and significant fact that the eskers referable to each stage of the glacial lake trend, in general, toward the nearest outlet of that stage, and that they are, as a rule, confined to the side of the valley (southeast and south) in which the outlets occur. Their absence from the middle of the valley would, however, be satisfactorily explained by the subsequent erosive action of the river. Very obviously, the subglacial drainage, moving in general up hill, with reference to the contours of the valley, in obedience to the hydrostatic pressure due to the great thickness of the ice-sheet to the northward, became more and more concentrated toward the outlets. A certain regard for the topography is thus indicated; but the unmistakable fact that the esker-building streams of the Boylston stage virtually flowed right by the South Dike outlet of the Clinton stage to seek much higher and more distant outlets then uncovered, shows that proximity to the margin of the ice was a still more potent factor than the topography in controlling and directing the subglacial drainage. It may be noted in passing, also, that we have in this indifference of the Boylston drainage to the Clinton outlet very convincing proof that the general trend of the ice margin at this time was northwest-southeast; for unless the ice had rested heavily upon the country to the east and southeast, it is inconceivable that the water could have resisted the natural tendency to escape by the South Dike outlet.

The only distinct or important occurrence of modified drift on the north side of the valley which can be referred to the Boylston stage of Lake Nashua is that in the vicinity of West Boylston Village and between West Boylston and Oakdale. It is very much subdivided and isolated by subsequent erosion; but we have one remarkable perfect remnant in the beautiful plateau rising abruptly on the east side of the village. This eroded plain, 440 to 460 feet in height, was probably once continuous with that at Oakdale and Boylston Common, filling the entire valley to this level, as far down, possibly, as Sawyer's Mills. The erosive action of the river and its tributaries upon this plain has been very great, so that only discontinuous marginal remnants or terraces now remain; and the fact that these are now more extensive and continuous on the south than on the north side of the valley is an indication that it suffered from the erosive action of glacial streams during the subsequent Clinton stage of Lake Nashua. The eskers in the valley of Stillwater River probably mark the shifting course of a subglacial stream tributary to the earliest stage of this plain.

It may be noted in passing that the draining of the Quinepoxet stage of Lake Nashua exposed its sediments to rapid erosion, thus supplying a part, possibly a large part, of the material for the upper (western) section of the Boylston plain, and making more probable the former continuity of this plain above Muddy Brook.

Northward from West Boylston the modified drift is continuous, across a low divide northwest of French Hill, with the very perfect plain in the south part of Sterling which embraces the Washaccum Ponds. The normal elevation of this plain is about 460 feet; and it is separated by a low divide from the gently sloping plain of about the same elevation, extending up the valley of Stillwater River toward West Sterling. A low ridge of rock and till across the east end of the Washaccum Valley, reinforced, probably, by the retreating margin of the ice-sheet, prevented the water which formed the Washaccum plain from finding an outlet to the eastward. This water probably communicated with the main body of Lake Boylston at Oakdale, through the pass occupied by the railroad and a branch of Stillwater River, and the modified drift crossing the low divide southward to West Boylston Village may, perhaps, be attributed to an earlier, subglacial, flow of water. The Washaccum plain rises gradually northward along the line of the railroad to the narrow and sharply-defined pass at Sterling Center, between this valley and the valley of Wekepeke Brook; and this sloping head of the plain was clearly formed chiefly by an overflow stream from an independent glacial lake in the Wekepeke Valley; but an earlier, subglacial flow along this line is indicated by a still traceable line of eskers. East Washaccum Pond clearly represents a part of this basin which was not covered by the delta, another indication that the main flow of water was not to the eastward, while West Washaccum Pond and Muddy Pond may, apparently, be regarded as true kettle ponds.

The high slopes of rock and till bordering the basin of Lake Boylston on the north make it unnecessary to postulate an ice barrier for the maximum stage of the lake, or to suppose that the delta plains were built against a wall of ice, except east of Sawyer's Mills, where, as previously noted, an ice margin is clearly indicated. I conclude, therefore, that at the close of this stage of Lake Nashua the more or less lobate front of the ice extended, as shown on the maps, from the South Dike pass westward across the main valley to the high ground about the head of Cunningham Brook, and thence northward across

the group of drumlins between Coachlace Pond and the Washaccum Ponds.

During the lowering of the water by the uncovering of the South Dike pass, a marginal stream flowing along the front of the ice-sheet, or possibly a glacial or subglacial stream, formed the small plain immediately north of Sawyer's Mills, which rises somewhat abruptly above the Clinton plain on the north (Pl. 3), to elevations of 395 to 405 feet, being distinctly intermediate between the Boylston and Clinton levels. Southward, toward the river, this little plain, which was virtually formed in an embayment between the ice on the north and the land on the west, is cut off by the steep modern erosion scarp, and we cannot observe its relations in this direction to the other plains. It is very improbable, however, that it ever extended far beyond its present limits. Westward, as we should naturally expect, the modified drift referable to this plain gains in height and approximates to the Boylston level.

The Clinton, Wekepeke and Ayer Stages.

When the ice margin had retreated along the eastern water parting to the pass now occupied by the Central Massachusetts Railroad, and to be later closed by the South Dike, the level of the lake was lowered nearly 100 feet to the Clinton stage; and its waters probably became tributary, the Concord and Merrimac Valleys being still occupied by ice, to Boston Harbor instead of Narragansett Bay. This is an ideal outlet — narrow, well defined, and with every indication of a strong stream flowing swiftly down around Snake Hill into the valley of North Brook (Pl. 4). In the lower part of its course, especially, this stream washed away all the finer part of the till, and its path is now strewn with thousands of residuary bowlders. That this is the work of a long-continued torrent, and not of some transitory cloud-burst, is proved by the pot-holes to be seen in the bed of North Brook at West Berlin, in situations which make it well-nigh impossible that they can have been formed by the modern brook.

The minimum elevation of the water-parting in the South Dike pass is 365 feet, or nearly 370 feet before the construction of the railroad. The elevation of the bed-rock surface at the same point is 358 feet; but to the east and southeast, as shown by the numerous borings, the bed-rock surface falls off for some 200 feet to elevations of about 340 feet (minimum 339.3), and then rises gradually again,

PLATE 3.

View looking southwest across the Clinton Plain at a marginal plain of the Boylston Stage of Lake Nashua. Both plains are cut off on the left by the erosion-bluff of the Nashua River in the vicinity of Sawyer's Mills.

PLATE 4.

View looking north across the South Dike Pass, or the outlet of the Clinton Stage of Lake Nashua. It shows a small portion of the Clinton Plain, and, in the distance, Burdette Hill on the left, Carvill Hill in the center, and Larkin Hill on the right. The course of the Outlet Stream was from left to right, along the line of the railroad.

reaching in 150 feet farther elevation 354. There is no evidence of a distinct bed-rock gorge here, but rather of a wide col or saddle with gentle slopes in all directions.

Plate 4 is a comprehensive view across this outlet, looking northward from a distinctly drumloid slope of till on the northwest side of Mile Hill (— feet, muscovite granite), with Burdette Hill (530 feet, porphyritic granite) in the distance on the left, Carvill Hill (535 feet, a broad dome of porphyritic granite) in the center, and Larkin Hill (560 feet, diorite and quartzose schist) on the extreme right. To the right of Larkin Hill, and well beyond the limits of this view is Snake Hill (— feet, muscovite granite). Between Burdette Hill and Carvill Hill, excavated in a band of soft phyllites, is the gorge of the Nashua River. Between Carvill Hill and Larkin Hill is Clam Shell Pond. The north side of the outlet is immediately formed by an undulating ridge of diorite, which, with elevations of from 390 to 410 feet, and thinly covered at most points by modified drift, extends northeastward for nearly half a mile to the base of Carvill Hill.[1] Of the two roads crossing the railroad in the foreground, the nearer one is the old road, shown on the map, and the farther one is the new road, built to take the place of this. The South Dike will start from the slope of till between the two roads, and cross the outlet nearly parallel with the old road (See map) to the low ridge of diorite, and then turn to the northeast along the top of the ridge.

The axis of the bed-rock depression in this pass does not follow the line of the railroad, but, crossing the railroad near the new highway, it bears to the southwest, passing obliquely under the slope of bowlder clay in the foreground of Plate 4, following the granite diorite contact regardless of the drift contours. As the plate clearly shows, the till, from a part of which the surface soil has been removed, extends north to the railroad; while the brushy slope north of the railroad is modified drift — the edge of a small development of the

[1] When discussing, in the paper on the geology of the dam and tunnel (Vol. XII., p. 76), the relations of the diorite to the muscovite granite I omitted to cite the evidence of the South Dike borings. The diamond drill borings are especially important in this connection. The cores show normal development of both the diorite and granite; that the contact is near the railroad and the axis of the depression; that the granite slopes down to the northward under the diorite; that there are dikes and dikelets of granite in the diorite; that, while the diorite retains its normal texture up to the contact, the granite becomes near the contact fine-grained and finely laminated or gneissoid (flow-structure); that the two rocks are firmly welded together; and, finally, that it is in every respect a typical contact, not due to faulting, and resembling that between the diorite and the porphyritic granite.

Clinton plain (380–385 feet). These facts make it clear that the pass is, and must have been during the existence of Lake Nashua, filled to a depth of twenty-five or thirty feet with bowlder clay; and hence we cannot suppose that the outlet stream flowed upon the bed-rock surface at its lowest point, nor necessarily at any point. In fact, it seems most probable that the stream flowed across the till regardless of the bed-rock contours, and that erosion soon developed a pavement of residuary bowlders, of which there are indications in the photograph, which greatly retarded the deepening of the channel. Another factor, which operated to the same end, is the slight fall of the outlet valley for the first half mile, insuring a placid current of slight erosive power. The broad channel of this stream is now a meadow which crosses and recrosses the road to West Berlin, and describes a full semicircle before returning to the railroad southwest of Snake Hill. In rounding Snake Hill the valley steepens, and a rush of water is indicated by the profusion of residuary bowlders previously noted.

With the opening of the South Dike pass came a rapid development of the Clinton plain, made possible by the necessarily rapid erosion of the high and deep deposits of the Boylston stage. In fact, the waste of the Boylston plain along the axis of the valley in the first few years after it became exposed to the rush of the Nashua and its tributaries with a fall of from 10 to 20 feet per mile must have been enormous; and we cannot escape the conclusion that through the coöperation of the Nashua with the glacial streams from the northward the Clinton plain was developed continuously along the southern margin of the ice to the outlet, the level of which was probably raised somewhat by the extension through it of the coarse topset layers of the delta.

The continued recession of the ice margin uncovered in succession the two passes of slightly greater but approximately equal elevation at the Acre, above the Lancaster Mills, and at Bolton Station. Judged by the rock contours, these passes are much higher than the South Dike pass, for the bed-rock (porphyritic granite) comes to the surface in both of them; and they were, therefore, less subject to changes of level through the washing away of the drift by ex-current streams. It is quite possible, however, that during the vicissitudes of erosion, deposition, ice dams, etc., all three of the Clinton passes were brought into play as outlets for the waters of the Clinton stage; although the South Dike pass, through its more southern location and consequent

earlier discovery, and greater depth, especially as measured on the bed-rock, must be regarded as the main outlet. The slight amount of modified drift in the valley immediately southeast of the Acre is not suggestive of any important outflow of water at this point; but we must recognize that an ex-current stream flowing over a granite dam could not be well charged with detritus. Extending northeastward from the Acre along the steep slope above the Nashua River, and on the general level of this pass, is a more or less distinct terrace of modified drift which is conceivably but not probably a marginal remnant of a once continuous plain extending westward across the basin. More probably, it is a free beach deposit; or perhaps, and with still greater probability, it marks the channel at an earlier period, when the valley was still filled with ice, of a marginal stream due to the interception of the drainage from the ice by the ridge of granite. The latter explanation is certainly demanded at Bolton Station, where this bench of modified drift widens into an undulating plain through which the railroad makes a deep cut. The former extension of this plain across the wide and deep valley is highly improbable; its breadth and volume, and its position in the lee of the large hill northeast of Clinton, forbid regarding it as a beach deposit; and the only alternative, apparently, is to consider that it antedates the complete evacuation of this part of the valley by the ice and was formed by glacial streams in a marginal embayment of the ice. Farther north, at the same general level, on the side of the valley above Still River and Lancaster Commons, are eskers trending in the direction of this embayment and the pass at Bolton Station. The glaciated and *roche moutouee* outlines of the porphyritic granite in this pass would seem to indicate that the outflow of water at this point, whether from Lake Nashua or an anterior marginal lakelet, was not very prolonged. But, on the other hand, we find sloping away from this pass to the east and southeast, into the valley of North Brook, a beautiful and almost ideal apron plain, a nearly perfect alluvial cone, which testifies unequivocally to an outflowing stream well charged with detritus, and hence quite certainly a marginal stream. That it was a short-lived stream and came to an abrupt end, probably when the continued waning of the ice allowed it to reach the South Dike pass, is indicated by the absence of fluvial erosion on the granite and the absence of erosion channels in the apron plain, such as must have been developed during a gradual slackening of the flow.

Pauses in the recession of the ice margin are rather seldom indicated by distinct morainal accumulations in this region, showing, apparently, that on this rugged surface, with strong gradients to overcome, the ice had already become essentially stagnant. But we have, perhaps, a slight exception, dating from the Clinton stage, in the basin of Clam Shell Pond, which is enclosed by and appears to be due wholly to two short but very typical moraines crossing the valley between Carvill Hill and Larkin Hill. The northern moraine is a particularly fine and strong example, with a great profusion of large bowlders. The southern moraine is more irregular and its low eastern end determines the water level of the pond (400 feet). The elevation of the bottom of the pond is 370 feet, or about the same as the Clinton outlets of Lake Nashua.

The delta plains of the Clinton stage, with normal elevations of 375 to 385 feet, are most broadly and typically developed in the districts immediately northwest and southwest of the village of Clinton, or in that part of the valley between South Lancaster and Boylston (Sawyer's Mills). They are, in part, indicated with a good degree of accuracy by the contour lines of the topographic map; and those southwest of Clinton are still more clearly and accurately expressed by the contour line of 370 feet on the map of the Wachusett Reservoir (Pl. 2), this contour tracing the outlines of the plains very closely where they are developed to the normal elevation. Although, as previously noted, the Clinton plains must, in consequence of the generous supply of material afforded by the fluvial erosion of the Boylston plain, have been developed continuously or nearly so over all the upper part of the valley, the postglacial erosive action of the river has left, as a rule, only meager remnants of it above Boylston; and above West Boylston it merges with or is lost in the modern flood plain of the river. North of Boylston the valley is much broader, and the ravages of the river relatively much less, so that over an area of several square miles the deltas of the Clinton stage are preserved almost intact. In fact, it may be doubted if anywhere in this region can be found more normal or striking examples of this phase of the modified drift. The deforesting of the area to be covered by the reservoir brings out the various features of the plains, ice margins, normal delta fronts, eskers, kettles, erosion slopes, etc., in all their pristine distinctness and perfection, so that even in a merely topographic sense a very unusual opportunity is temporarily presented to the student of

glacial geology. But in addition to this, the numerous deep borings in the vicinity of the North Dike, and the subsequent deep cut-off excavation in the construction of the dike itself, have thrown a flood of light upon the structure and composition of these plains. These considerations, collectively, demand such a thorough and detailed study as would carry us beyond the reasonable limits of this paper; and the further special consideration of the Clinton plains, which are unquestionably equal in interest to all the rest of the modified drift of the Nashua Valley, is, therefore, reserved for a second paper.

North of Clinton the ice margin appears to have retreated too rapidly to permit the formation of extensive plains of normal height in water from 100 to 250 feet deep, and the broad level plain, forming the bottom of the valley 260 to 280 feet in height may be referred to the next lower (Ayer) stage, which began when the recession of the ice uncovered the broad and deep pass connecting the modern valleys of the Nashua and Stony Brook. To this stage may be referred the plain in South Lancaster on the northern lobe of which Lancaster Commons stands. This is a remnant of the delta formed in the head of the lake from the waste of the Clinton plains. But the chief deltas corresponding to the level of the Ayer outlet are the broad plains south and west of Ayer Junction.

The valley of Wekepeke Brook lying west of the Ballard Hill ridge had for a time an independent lacustrine history. When the ice covered the notch in this ridge occupied by the Boston, Clinton & Fitchburg Railroad, the water stood at an elevation of about 500 feet and discharged southward through Sterling Center, along the line of the Fitchburg & Worcester Railroad, into the Washaccum area of the Boylston stage, making an important contribution in the form of an apron plain to the 460 feet plain enclosing the Washaccum Ponds. Later the water found the eastern notch referred to, and, its level falling to about 420, it became tributary to the Clinton stage. That this condition did not long continue is indicated by the absence of any important plain development of corresponding height in the Wekepeke Valley.

The exceptional heights reached by the modified drift along the east side of the valley in Lancaster, and about Ban Hill Pond in Harvard, are probably best explained by deposition in marginal lakelets, while the ice still filled the valley.

My detailed study of the modified drift has not extended over the

Groton and Fitchburg quadrangles of the topographic map, and I am not fully prepared to explain the extensive plain or mass of modified drift having a normal height of 400 to 420 feet, lying between the Fitchburg Railroad on the north and the North Nashua River on the south. I can only suggest that, perhaps during the Wekepeke stage, and while the ice in the main valley was still joined to the Ballard Hill ridge, a great embayment was formed whose level was determined by the outlet in the upper Wekepeke Valley. A rational explanation of such an embayment may be found in the principle formulated by Chamberlin that in the case of ice moving on an elevated broken surface the loss by ablation is not promptly made good by an influx from the north, and a depression results. A complete land barrier is out of the question, and since this material must have been deposited in an embayment of the ice, it seems best to correlate it with the lower Wekepeke outlet. The same expansion of the Wekepeke stage would explain the modified drift extending up the valley of the North Nashua as far as Fitchburg. All of this harmonizes well with the idea that the ice margin receded northeastward across this region, maintaining a general northwest and southeast trend.

When the ice retreated from the divide at East Pepperell, with an elevation of about 200 feet, the Ayer outlet across a broad barrier of till at an elevation of 260 to 280 feet was abandoned, and the history of Lake Nashua practically came to an end. In the course of postglacial time the river has trenched the deposits formed in the successive stages of the glacial lake, first grading its channel and then steadily widening its flood plain, where not hemmed in by the hard rocks or masses of bowlder clay.

REVIEW

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INORGANIC CHEMISTRY.

HENRY FAY, REVIEWER.

A Reduction of Permanganic Acid by Manganese Peroxide. BY H. N. MORSE AND C. L. REESE. *Am. Chem. J.*, 20, 521–535.—In a previous paper (*this Rev.*, 2, 85) it was shown that permanganic acid decomposes in presence of manganese dioxide and a reduction of the acid takes place with the liberation of three-fifths of its active oxygen. It was suggested later that this phenomenon might explain the evolution of oxygen which takes place when hydrogen or carbon monoxide is absorbed by a five per cent. acidified solution of potassium permanganate. H. Hirtz and V. Meyer maintained that the phenomenon of the evolution of oxygen observed by Meyer and Von Recklinghausen was fundamentally different from that observed by Morse, Hopkins, and Walker, because the latter experimented only with *neutral* solutions, and the evolution of oxygen which occurs *during the absorption* is much more rapid than that which takes place *after the exhaustion* of the gas. The authors point out that the first objection is invalid; for out of 48 experiments 35 were made with acidified permanganate solution. In regard to the second objection, the suggestion is offered that the rapid initial evolution of oxygen is in some way connected with the nature of the gaseous reducing agent or that the initial peroxide molecules are of greater simplicity. Meyer and von Recklinghausen obtained about 1.9 to 2.9 cc. of oxygen when air was shaken with a five per cent. acidified solution of potassium permanganate which had been previously boiled, and they believed that there was a definite limit to the evolution of oxygen. The authors show that boiling with sulphuric acid produces man-

ganese dioxide, which may be the cause of the decomposition, and that there is a gradual, but continuous, decomposition with continued shaking. Working with three solutions which contained respectively 2.822, 5.644, and 51 milligrams of $KMnO_4$ in each cubic centimeter, and which had been filtered through two layers of asbestos, it was shown that the two weaker solutions suffered no appreciable loss of oxygen when shaken 150 to 300 hours, whether the acid added was equivalent to once or six times the potassium of the permanganate. In the strongest solution there was no appreciable loss of oxygen except when the acid present amounted to three times that of the potassium, and even then after agitating 150 hours was not so large as that observed by Meyer and von Recklinghausen. A series of experiments were made to determine the relative rates of reduction when equal volumes of permanganic acid are agitated, on the one hand with a given volume of hydrogen, and on the other with a quantity of peroxide which is equal to that produced by the absorption of all of the hydrogen. The same three solutions were used and were shaken at times varying from 24 to 300 hours and with an equivalent to all of the potassium and to thee times as much. The experiments show that hydrogen as a reducing agent is much more efficient during the first 24 hours than manganous sulphate with the two stronger solutions. During the period from 24 to 150 hours, the oxide produced by hydrogen acted much more rapidly in the permanganate solution containing 51 milligrams $KMnO_4$ than the oxide produced by the manganous sulphate. In the two more dilute solutions this order is reversed. During the period of shaking, from 150 to 300 hours, the oxide produced by hydrogen was decidedly less active than that from manganese sulphate. In the presence of oxide there seems to be no limit to the reaction until all of the permanganic acid is used up.

On the Metaphosphimic Acids (III). By H. N. Stokes. *Am. Chem. J.*, 20, 740–760.–In two preceding papers (*this Rev.* 3, 4–7) the author has described trimetaphosphimic and tetrametaphosphimic acids odtained from the corresponding phosphonitrilic chlorides, $P_3N_3Cl_6$ and $P_4N_4Cl_8$. He now prepares and describes the next higher members of this series, the pentametaphosphimic and hexametaphosphimic acids, $P_5N_5(OH)_{10}$ and $P_6N_6(OH)_{12}$, by acting on the chlorides with sodium acetate. It is found that there is a close analogy between this series of acids and the series of methylene ring hydrocarbons, and that with respect to stapility, power of forming lactones, and the nature of the decomposition-products, the properties of these acids may be explained by stereochemical considerations analogous to those of von Baeyer on the methylene hydrocarbons and of Wislicenus on the lactones. Assuming that the metaphos-

phimic acids are phosphorus-nitrogen ring compounds, and that the mean angle for an eight-membered ring, which is the most stable condition, is 135°, the properties of the other acids may be deduced from this. From the following table it will be seen that as we ascend in the series there is a very rapid increase of stability to a maximum, followed by a gradual decrease. This is in accordance with the experimental data. $P_5N_5(OH)_{10}$ is less stable than $P_4N_4(OH)_8$, but markedly more stable than $P_3N_3(OH)_6$, corresponding to the difference of only 9° from 135° in one case against 15° in the other.

Ring.	Number of sides.	Mean angle.	Difference from 135°.
PN	2	0°	−135°
P_2N_2	4	90°	− 45°
P_3N_3	6	120°	− 15°
P_4N_4	8	135°	0°
P_5N_5	10	144°	+ 9°
P_6N_6	12	150°	+ 15°
P_7N_7	14	154·3°	+ 19·3°
P_8N_8	16	157·5°	+ 22.5°

The acids containing 1 and 2 atoms of phosphorus are unknown; those containing 3, 4, 5, and 6 atoms of phosphorus have been isolated and exist in two atoms, the lactam form, $(PNO_2H_2)_n$, where *n* is either 3, 4, 5, or 6, which is formed only in neutral or acid solution and the open chain form $(PNO_2H_2)_n + H_2O$ formed under the influence of alkali. The acid corresponding to the chloronitride, $P_7N_7Cl_{14}$, and possibly those from the higher members, exist only in the open chain form. The higher members of the series break down into the more stable form containing four atoms of phosphorus. Pentametaphosphimic acid breaks down under the influence of mineral acids into tetrametaphosphimic acid, triimidotetraphosphoric acid, diimidotriphosphoric acid, and orthophosphoric acid. The sodium and silver salts of penta- and hexametaphosphimic acids in which the metals replaced one-half of the hydrogen, were prepared. Unsuccessful attempts were made to prepare the amides of the metaphosphimic acids by treating the chloronitrides with strong ammonia.

On the Claims of Davyum to Recognition as a Chemical Element. By J. W. Mallet. *Am. Chem. J.*, 20, 776–783.—Davyum has been described by Kern as having been obtained from platinum ores. He found its atomic weight to be 154, and one of its characteristics was the insoluble double sodium salt. The material investigated by the author was obtained from a London manufacturer of platinum: the filtrate from the aqua regia solution, after decantation from osmiridium and separation of the platinum by means of ammonium chloride, had been evaporated to dryness with sodium chloride. On taking this up in a small quantity of water, the insoluble residue, where davyum

should be found, was proved by the author to be a mixture of finely divided quartz, zircon, and osmiridium. In the precipitation of platinum from certain liquors, ammonium chloride saturated with sodium chloride is used. By evaporation of the filtrate there was formed a buff-colored powder consisting of octahedra. The metal was reduced by pure zinc, dissolved in aqua regia, the sodium double salt again made, dried, weighed, and reduced in hydrogen. Assuming the formula for the double salt to be Na_2MCl_6, the atomic weight of the metal was deduced as 151.5, which agrees closely with Kern's value. The properties of the metal obtained were similar to those described for davyum, but it was shown to consist of iridium and rhodium in about equal amounts and of a trace of iron.

The Formation of Alums by Electrolysis. By Jas. Lewis Howe and E. A. O'Neal. *J. Am. Chem. Soc.*, **20**, 759–765.—Solutions of metals in the lower state of oxidation were electrolyzed in a platinum dish, which formed the positive electrode, in presence of sulphuric acid and the different alkali sulphates. The rubidium and caesium iron alums and the rubidium and caesium cobalt alums were prepared in this way.

Derivatives of the Tetrachlorides of Zirconium, Thorium, and Lead. By J. Merritt Matthews. *J. Am. Chem. Soc.*, **20**, 815–839.—By bringing together ethereal solutions of the tetrachlorides of zirconium, thorium, and lead, with different substituted ammonias, direct addition takes place. Four molecules of methyl, ethyl, and propyl amines are added to each of the tetrachlorides. Zirconium tetrachloride combines with four molecules both of aniline and toluidine; thorium tetrachloride with four of aniline and three of toluidine; and lead tetrachloride with three of aniline, decomposing toluidine. Two molecules each of pyridine, quinoline, and naphthylamine combine with zirconium tetrachloride, one each with thorium tetrachloride, while lead tetrachloride combines with one of pyridine and naphthylamine, and two of quinoline. Under different conditions eight, six, and two molecules of ammonia add directly to zirconium tetrachloride; eight and six to thorium tetrachloride; and four to lead tetrachloride.

Derivatives of the Tetrabromides of Zirconium and Thorium. By J. Merritt Matthews. *J. Am. Chem. Soc.*, **20**, 839–843.—Zirconium tetrabromide adds itself directly to four molecules of ammonia, ethylamine, and aniline, and to three of pyridine; thorium tetrabromide adds directly to one molecule of pyridine, three of ammonia, and four of ethylamine and aniline.

Review and Bibliography of the Metallic Carbides. By J. A. Mathews. *Smithsonian Miscellaneous Collections, No.* **1090**, 1–32.

GENERAL AND PHYSICAL CHEMISTRY.

A. A. NOYES, REVIEWER.

New Experiments on the Quantitative Synthesis of Water. BY EDWARD H. KEISER. *Am. Chem. J.*, 20, 733–739.—The apparatus and method employed were as follows: A glass tube 5 ½ cm. in diameter, with a slight constriction two-thirds of the way down, was drawn out at the bottom and fused to a glass stop-cock, and was closed at the top with a ground glass cap provided with a three-way cock. The lower compartment of the tube, below the constriction, was filled with sublimed phosphorus pentoxide. The cap was put on, and the tube was evacuated with a Töpler air-pump and weighed. The cap was then removed, and a cylindrical tube, open above and perforated with a number of small holes near the bottom, filled with palladium sponge prepared by reduction with hydrogen, was inserted in the upper compartment above the pentoxide. The cap was instantly replaced, the tube exhausted, and a second weighing made. Hydrogen, made by electrolyzing dilute sulphuric acid and purified by passing through caustic potash, over heated palladium, to convert any oxygen present to water, and finally through U-tubes containing solid potash and phosphorus pentoxide, was slowly admitted through the three-way cock, until the palladium had become saturated. Then the excess of gas, together with any impurities contained in the total amount absorbed, was pumped out, and a third weighing made. The difference between this and the second weight was the amount of hydrogen converted into water by the next operation. This consisted in admitting very gradually electrolytic oxygen purified in the same way as the hydrogen. The union with the hydrogen absorbed in the palladium occupied four to five hours, and an excess of oxygen was then allowed to stand in the tube over night. This was then removed by drawing it out at the bottom through the phosphorus pentoxide, and the evacuated apparatus was weighed a fourth time, the difference between the third and fourth weights giving the weight of oxygen that had combined with the hydrogen. Finally, dry air was admitted, the cap was removed, the inner tube with the palladium taken out, the cap replaced, and the apparatus again weighed after evacuation. The difference between this last weight and the first one of all is the weight of water absorbed by the pentoxide. This should check, of course, with the sum of the weights of oxygen and hydrogen, if there is no error from incomplete drying of the gases or leakage. This was found to be very nearly the case in four out of the six experiments that were carried through. The data of these four experiments, which alone are communicated, are as follows:

Wt. of H.	Wt. of O.	Sum of H+O.	Weight of H_2O found.	At. wt. O (H = 1). From H_2:O.	From H_2:H_2O.
0.27549	2.18249	2.45798	2.45975	15.846	15.858
0.27936	2.21896	2.49832	2.49923	15.886	15.892
0.27091	2.15077	2.42168	2.42355	15.880	15.892
0.26845	2.13270	2.40115	2.40269	15.890	15.900
			Mean,	15.874	15.886

The mean of the two averages is 15.880, which is in complete agreement with the value found by Morley and other recent investigators.

On the Cause of the Retention and Release of Gases Occluded by the Oxides of the Metals. By THEODORE WILLIAM RICHARDS. *Am. Chem. J.*, **20**, 701–732.—Experiments are first described which show that samples of cupric oxide, prepared by heating cupric nitrate under different conditions, occluded and set free on treatment with acid, after being ignited for from ½ to 20 hours at temperatures varying from 500° to 830°, 0.55–0.70 cc. of gas for each gram of oxide. The amount of gas varies within the limits just stated with the original method used for converting the nitrate to oxide, but is independent in the case of a definite sample of the duration and temperature of the subsequent ignition as long as the temperature does not exceed 830°. Between 870° and 950°, however, most of the gas is gradually expelled, the rapidity depending on the temperature, and only about 0.05 cc. remains after ½ to 2 hours ignition at 950°. Similar experiments with zinc oxide prepared from zinc nitrate showed, on the other hand, that one gram of it retains, after heating for three hours at 660°, 0.37 cc.; at 750°, 0.22 cc.; and at 880°, 0.16 cc. of gas. The amount retained is thus seen to be dependent on the temperature of the ignition, and a special series of experiments showed that it also varies with its duration, and markedly with the method of preparation of the sample of oxide. Zinc oxide prepared from the carbonate contained no gas, and that prepared by heating the nitrate to 280° contained only 0.015 cc., previous to its ignition at higher temperatures. These facts make it clear that the occluded gas arises from the decomposition of a residue of basic nitrate left in the oxides in their preparation at low temperatures. Interesting experiments were also made on the proportions of oxygen and nitrogen in the gas in relation to the temperature and duration of the ignition, and it was found that both with copper and zinc oxide, as well as with magnesium oxide which had been previously investigated, the proportion of oxygen was much less, the higher the temperature and the longer the ignition. For example, the gas obtained by heating zinc oxide at 660° for three hours contained more than 60 per cent. of oxygen, while that from the oxide

kept at 880° for the same time contained less than 20 per cent., the absolute amount of nitrogen per gram being nearly the same in the two cases. The oxygen, therefore, escaped much more readily than the nitrogen. In order to explain this phenomenon, which cannot be due to diffusion or transpiration, the author assumes that the oxides are in a state of partial dissociation, and the continual formation and decomposition of oxide molecules enables the oxygen to pass out from within the solid particles. In support of this hypothesis, among other things, he proves that cupric oxide heated to 790° *in a vacuum* evolves nearly pure oxygen.

The Solubility of Salts of Weak Acids in Stronger Acids. By Arthur A. Noyes and David Schwartz. *J. Am. Chem. Soc.*, **20**, 742–751.—The authors have determined the solubility of silver benzoate in nitric and chloracetic acid solutions of various strengths, and have developed mathematically the theory of this phenomenon by applying the principles of mass action and electrolytic dissociation. The calculated effect of the acids in increasing the solubility agrees well with that observed.

The Solubility of Acids in Solutions of the Salts of Other Acids. By Arthur A. Noyes and Edward S. Chapin. *J. Am. Chem. Soc.*, **20**, 751–756.—The solubility of benzoic acid in sodium acetate and sodium formate solutions of various concentrations was determined. The theory of the effect is the same as in the preceding investigation, and close agreement between the observed and calculated values was found here also.

Benzaldoxime. By Frank K. Cameron. *J. Phys. Chem.*, **2**, 409–416.—The author has investigated the equilibrium conditions between the two stereoisomeric forms of benzaldoxime. He concludes that both forms exist in the liquid condition and that their relative concentrations are independent of the temperature. The stable triple point is 27.7° and at this point the mixture contains 94 per cent. of the α modifications. The eutectic point is at 25°–26°, the mixture then containing 91 per cent. of the α compound.

The Isothermal Pressure-Surface in the Case of Two Single Salts and One Double Salt. By F. G. Donnan. *J. Phys. Chem.*, **2**, 417–420.

The Molecular Weight of Orthorhomic, Monoclinic, and Plastic Sulphur in Naphthalene and Phosphorus by the Freezing-point Method. By Samuel D. Gloss. *J. Phys. Chem.*, **2**, 421–426.—The author concludes from his experiments that there is no difference in the molecular weights of the three forms of sulphur mentioned in the title in either of the two solvents mentioned.

Potassium Chloride in Aqueous Acetone. By J. F. Snell. *J. Phys. Chem.*, **2**, 457–491.—The author communicates the results of experiments in which the temperatures were determined at which numerous mixtures of the three substances, water, acetone, and potassium chloride, separated into two layers. These temperatures lie for the most part between 32° and 110°. He found that even at a very much higher temperature (250°–300°) such solutions do not in any case again become homogeneous. He has also determined the temperature of division of various mixtures of water and acetone saturated with potassium chloride, and the solubility at 30° and 40° of this salt in such mixtures. The graphic representation of the equilibrium conditions involved is discussed at length.

Alcohol, Water, and Potassium Nitrate. By Norman Dodge and L. C. Graton. *J. Phys. Chem.*, **2**, 498–501.—The authors have determined the temperatures at which various mixtures of water and alcohol containing from 13 to 85 per cent. of the latter separate into two distinct layers when kept saturated with potassium nitrate. These temperatures lie between 80° and 144°. The temperature of separation was found in one case to be 15° lower when an excess of potassium chloride was added at the same time with the excess of potassium nitrate.

A. A. Blanchard, Reviewer.

Cyclical Law of the Elements. By Thomas Bayley. *J. Am. Chem. Soc.*, **20**, 927–934.—The author discusses Lothar Meyer's curve of atomic weights and atomic volumes, and presents evidence that the sixth loop or cycle embraces elements with atomic weights between that of caesium and that of an unknown alkali metal of atomic weight 223, instead of 170, as Lothar Meyer suggested.

Atomic Volume as a Periodic Function. By Thomas Bayley. *J. Am. Chem. Soc.*, **20**, 935–948.—Constructing an atomic volume curve like that of Lothar Meyer, drawing ordinates through the points that mark the transitions from cycle to cycle which occur just before the alkali metals, lithium, sodium, potassium, rubidium, caesium, and the value 223.7, and drawing abscissae at points corresponding to atomic volumes of 30, 60, 90, 120, etc., the author shows that it is possible to draw straight lines through their intersections, which will also pass through the positions of two or more elements, and that there is a remarkable regularity in the properties of the elements located upon these lines. The position and properties of numerous un-

known elements in the sixth, seventh, and eighth cycles are also shown by extending the system of lines.

ANALYTICAL CHEMISTRY.

ULTIMATE ANALYSIS.

H. P. TALBOT, REVIEWER.

I. Metal Separations by Means of Hydrobromic Acid Gas. II. Indium in Tungsten Minerals. BY ELIZABETH ALLEN ATKINSON. *J. Am. Chem. Soc.*, **20**, 797–813.—It is shown that there is a marked similarity in the behavior of the metals when placed in an atmosphere of hydrobromic acid to that noted when hydrochloric acid is used. When volatilization of the bromine compounds occurs, however, it is less prompt than that of the chlorides, and certain of the metals, notably lead and cobalt, form oxybromides, while copper forms a cuprous bromide. Silver and cadmium are changed to bromides. Attempted separations of arsenic and iron in an atmosphere of hydrochloric acid as well as one of hydrobromic acid were both unsuccessful. The analysis of wolframite from Zinnwald and from Cornwall, of hübnerite from Colorado, and of scheelite from New Zealand and Bohemia showed the presence of indium only in the first-named mineral. This confirms the views of Hoppe-Seyler (*Ann. Chem.*, **140**, 247), that the indium in the specimen of wolframite from Zinnwald was probably present in the zinc blende. Zinc was absent from the other specimens.

IV. On the Separation of Iron from Zirconium and Certain Other Allied Metals. BY J. MERRITT MATTHEWS. *J. Am. Chem. Soc.*, **20**, 846–858.—Absolute ether, into which dry hydrochloric acid gas is passed, will separate the iron from a mixture of the zirconium and ferric compounds left after the evaporation of an aqueous solution of the chlorides on the water-bath, without dissolving any zirconium. The latter remains as the oxychloride, and the two metals may be quantitatively separated by this procedure. The same method was employed with practical success for the separation of iron from thorium, cerium, titanium, lanthanum, neodymium, and praseodymium.

The Determination of Sulphur in Asphalt. BY E. H. HODGSON. *J. Am. Chem. Soc.*, **20**, 882–889.—A comparison of the fuming nitric acid (Carius), deflagration, sodium peroxide, and Eschka methods leads the author to the conclusion that the first-named procedure gives the best results, but is long and precarious because of the bursting of the sealed tubes. Of the others, the author prefers the Eschka method.

On the Facilities for Standardizing Chemical Apparatus Afforded by Foreign Governments and Our Own. By Louis A. Fischer. *J. Am. Chem. Soc.*, **20**, 912–927.—The paper presents a brief history of the National Office of Standard Weights and Measures, and contains statements of the present facilities for the examination of instruments used by chemists, and the regulations governing this branch of the work of the office. The provisions made by foreign governments for similar purposes are briefly stated. A device for marking flasks for volumetric analysis is described in detail.

Some Errors in the Determination of Nitrogen. By C. G. Hopkins. *J. Am. Chem. Soc.*, **20**, 961–965.—In confirmation of Rempel's results (*Ztschr. angew. Chem.*, *1889*, 331), it is found that there is a loss of ammonia if its solution is exposed to the atmosphere during titration, even while dropping from a burette; and, also, that unless the tube from the condenser in the Kjeldahl method reaches to the bottom of the receiver containing the standard acid solution, the ammonia may accumulate in and supersaturate the upper layers, and escape.

W. H. Walker, Reviewer.

Further Separations of Aluminum by Hydrochloric Acid. By Frank Stuart Havens. *Am. J. Sci.*, **156**, 45–48.—The method of Gooch and Havens (*this Rev.*, **3**, 30) for the separation of aluminum from iron is here extended with little variation to the separation of aluminum from zinc, copper, mercury, or bismuth. After removal of the aluminum, the ether-acid solution is evaporated to dryness and the remaining metal determined by one of the usual methods.

The Iodometric Determination of Molybdenum. By F. A. Gooch and John F. Morton, Jr. *Am. J. Sci.*, **156**, 168–175.—In a former article (*this Rev.*, **2**, 68), Gooch and Fairbanks pointed out certain inaccuracies in the iodometric determination of molybdenum as proposed by Friedheim and Euler, and recommended modifications by which such inaccuracies might be eliminated. To this criticism Friedheim took exception, and the authors, having carefully repeated the former work, devote the present article to a review of the subject, and give data which fully substantiate previous conclusions.

On the Determination of Manganese as the Pyrophosphate. By F. A. Gooch and Martha Austin. *Am. J. Sci.*, **156**, 233–243.—The success of the analytical process by which manganese is determined as pyrophosphate depends upon the conversion of the amorphous trimanganous phosphate, $Mn_3P_2O_8$, which is at first precipitated, into the crystalline ammonium magnesium

phosphate, $MnNH_4PO_4$. The conditions under which this change may be most easily and completely brought about have been very thoroughly studied by the authors. They find that a large excess of ammonium chloride is necessary for the transformation, and that the following procedure gives the most satisfactory results: The slightly acid solution, containing in a volume of 200 cc. an amount of manganese not more than enough to make 0.4 gram of pyrophosphate, 20 grams of ammonium chloride, and 5 to 10 cc. of a cold saturated solution of microcosmic salt, is precipitated in the cold by the careful addition of ammonium hydrate in slight excess. On heating, the precipitate quickly becomes silky and crystalline, and may be filtered, washed, and weighed as usual.

Detection of Sulphides, Sulphates, Sulphites, and Thiosulphates in the Presence of Each Other. By P. E. Browning and Earnest Howe. *Am. J. Sci.*, **156**, 317–322.—The method of R. G. Smith (*Chem. News*, **72**, 39) for the detection of the above-named radicals in the presence of each other has the two serious drawbacks, that the hydrochloric acid necessary to dissolve the barium sulphite and thiosulphate frequently breaks up the thiosulphate with the separation of sulphur, and that a very small precipitate of barium sulphate is difficult to recognize in solutions colored by iodine and bromine. The authors have been able to overcome these difficulties by using the following modifications of the original method: About 0.1 gram of the substance, dissolved in 10 cc. of water, is made slightly alkaline with ammonia or sodium hydroxide, and a little zinc acetate added, precipitating any sulphide present. The filtrate is made slightly acid with acetic acid, and the sulphate present thrown out of solution by means of barium chloride. Iodine is now added to the filtrate free from barium sulphate until the color is permanent, and the excess then removed by a few drops of a stannous chloride solution (to which has been added a little hydrochloric acid to prevent the precipitation of basic tin salts). A precipitation of barium sulphate at this point indicates that a sulphite was originally present. The thiosulphate which has been changed to tetrathionate by the iodine, is now further oxidized to sulphate by means of bromine water, the excess being removed by stannous chloride as before, and its presence is now indicated by a third precipitate of barium sulphate.

The Estimation of Boric Acid. By F. A. Gooch and Louis C. Jones. *Am. J. Sci.*, **157**, 34–40.—Owing to the difficulty of obtaining definite conditions for weighing the calcium oxide used to retain and estimate boric acid when distilled with methyl alcohol from an acid solution, numerous substitutes have from time to time been proposed. The experimental data given

in the present article show, however, that none of these are superior to calcium oxide if the precautions given in Gooch's original article are followed. A retainer which is much less hygroscopic and in every way suitable, is found by the authors in sodium tungstate which has been fused with a small excess of tungstic acid. It may be used in a manner similar to the other substances with very satisfactory results.

The Standardization of Volumetric Acid and Alkali. By W. A. PUCKNER. *Pharm. Archives*, 1, 172–184.—The advantages and disadvantages of a number of the substances frequently used for standardization are discussed, and a large number of experimental data are communicated. The writer, however, "refrains from drawing conclusions."

PROXIMATE ANALYSIS.

A. G. WOODMAN, REVIEWER.

On Acetic Acid as a Substitute for Ethyl Alcohol in Extracting the Active Principles of some Officinal Drugs. By EDWARD R. SQUIBB. *Am. J. Pharm.*, 71, 1–14.—In order to measure the comparative capacity of alcohol and acetic acid for extracting the active principles of drugs, the author has made parallel extractions of nux vomica, a drug most difficult to extract completely. The results, obtained by the process of repercolation, using siphon percolators, show in general that by the substitution of the acetic acid menstruum for the alcoholic, one-half the cost of grinding, and five-sixths of the cost of menstruum, are saved, an equivalent product being obtained in larger quantity. The acid preparation has a larger proportion of inert extractive matter, but it gives much less precipitation on dilution than the alcoholic, and that which it does give is not liable to carry down alkaloids soluble in an acid solution. After trying various methods in the endeavor to secure a convenient and fairly accurate process of assay for the mixed alkaloids, the following procedure was adopted: 10 grams of nux vomica, ground to pass through a No. 9 sieve, is exhausted with 10 per cent. acetic acid. The percolate is evaporated to dryness on the water-bath and then dissolved in 10 cc. of a mixture of two volumes alcohol (91 per cent.), one volume ammonia water (10 per cent.), and one volume water. The alkaloids are extracted from this solution by a mixture of equal volumes of chloroform (99 per cent.) and ether (96 per cent.). The chloroform extract is evaporated, the soluble alkaloids taken out by warming with 10 cc. decinormal sulphuric acid, and the final solution titrated with decinormal potassium hydrate, using logwood as an indicator.

A Common Error in Recorded Results of Proximate Plant Analysis. By Lyman F. Kebler. *Am. J. Pharm.*, 71, 25–26. —The author calls attention to the error caused by adding the percentage of ash to the percentage of the other constituents instead of estimating it in the dried residue left after the action of the various solvents.

Coumarin and Vanillin, Their Separation, Estimation, and Identification in Commercial Flavoring Extracts. By William H. Hess and Albert B. Prescott. *Pharm. Rev.*, 17, 7–9.—The method for the separation of vanillin and coumarin proposed by the authors, is based on the aldehydic character of vanillin, which is hydroxymethoxybenzoic aldehyde, while coumarin is the anhydride of coumaric (orthohydroxycinnamic) acid. From 25 to 100 grams of the commercial extract are heated at about 80° C. until the alcohol is evaporated, and a solution of lead acetate is added until no more precipitate forms. The filtered solution is extracted with ether, and the vanillin in the ether extract is shaken out with dilute ammonia. The ether solution is then evaporated over sulphuric acid, and the coumarin in the residue is taken up with ligroin, being obtained in crystals melting at 67° C. upon evaporation of the solvent. The ammoniacal solution is made slightly acid and shaken out with ether as before. After evaporation the vanillin is extracted from the residue by boiling ligroin. It gives a pure crystalline product melting at 80°–81° C. This method was found to give satisfactory results.

Emetine Octoiodide and the Extraction and Estimation of Alkaloids Generally. By H. M. Gordin and A. B. Prescott. *Am. J. Pharm.*, 71, 14–21.—In estimating the alkaloids in medicinal drugs, the simplest and best method of obtaining the alkaloidal solution free from foreign matter is that of Lyons (*Manual Pharm. Assaying, 1886*, 20). By evaporation of the highly volatile solvent used, however, the results are liable to be high; and, in order to avoid this, the authors have worked out a different method of alkaloidal extraction which is in general the same as that proposed by them for the assay of opium (*J. Am. Chem. Soc.*, 20, 724; *this Rev.*, 4, 115). The method was found to give good results with various drugs, with the exception of ipecac root. It was also found that the separate estimation of strychnine and brucine in nux vomica could be conveniently made by the periodide assay method together with a modification of the method of separation proposed by Dunstan and Short (*Am. J. Pharm.*, *1883*, 579). Emetine octoiodide was prepared and analyzed. It was obtained as a dark-brown powder, difficultly soluble in benzol, ether, or chloroform, quite readily soluble in

alcohol, and very soluble in a mixture of alcohol and chloroform. It appears to be emetine hydriodide heptaiodide, $C_{28}H_{40}N_2O_5.HI.I_7$, corresponding to the formula for emetine found by Lefort and Wurz (*Ann. chim. phys.* (5), **12**, 247).

Comparison of Methods for Estimating Caffeine. By E. F. Ladd. *Am. Chem. J.*, **20**, 866–869.—The author has made comparative determinations of the value of four methods for the estimation of caffeine in tea. The methods employed were those of Vite, Peligot, Crosschoff, and Gomberg. The method of Vite gave a loss of 10 per cent. on pure caffeine, and a loss of as much as 42 per cent. when working with tea. The other three methods gave good results with pure caffeine. The percentages of caffeine found in three samples of tea are given in the following table:

Method.	Congo tea.	Green tea.	Gunpowder tea.
Peligot	0.843	2.061	3.680
Crosschoff	0.919	2.031	3.200
Gomberg	1.542	2.386	3.986

The higher results given by Gomberg's method, together with its simplicity, make it the most desirable method for the rapid determination of caffeine.

Methods for the Determination of Color and the Relation of the Color to the Character of the Water. By Frederick S. Hollis. *J. N. E. Water Works Assoc.*, **13**, 94–111.—The author shows by a series of analyses, extending over a year, that in an unpolluted surface water the variations in oxygen consumed, loss on ignition, and albuminoid ammonia, in general, follow the changes in color. Among the methods for the determination of color are described the Tidy colorimeter, the Nessler scale of Leeds, the method based on a comparison of the natural waters with the Lovibond tintometer (erroneously spelled Lovi*bard*), the platinum scale of Hazen, and the special form of colorimeter used at the Experimental Filter Station of the Boston Water Works. A table is given for the conversion of color readings from the Nessler and natural water standard to the platinum standard.

TECHNICAL CHEMISTRY.

F. H. Thorp, Reviewer.

The Influence of Bismuth on Brass and Its Relation to Firecracks. By Edwin S. Sperry. *American Machinist*, **21**, 690–692.—The author investigated the truth of the maxim common among brass founders that bismuth is injurious in brass. Five experiments were made in which a pure Lake Superior copper

was melted and a certain quantity of a definite alloy of copper and bismuth introduced. Pure refined zinc was then added and the brass cast in a mold. It was then rolled cold. The presence or absence of cracks on the edges and surface of the plate was noted. The plate was then annealed and again examined for fire-cracks; if these were not sufficiently deep to prevent further treatment, the plate was again rolled and examined. The amount of bismuth introduced varied from 0.5 per cent. to 0.02 per cent., and in all cases the amount of cracking was proportional to the quantity of bismuth present. Less than 0.02 per cent. bismuth would produce a satisfactory brass. The author believes he has demonstrated that bismuth is a cause of fire-cracks in brass, but it is not commonly present in sufficient quantities to be considered the *only* cause of them. His results in brief are: Bismuth renders brass cold-short, but has less effect than antimony in this respect; it causes fire-cracks, and brass for cold rolling should not contain over 0.01 per cent. of bismuth; it also causes hot-shortness and latent fire-cracks, *i. e.*, lines of inferior cohesion after annealing which develop into cracks when the brass is rolled.

The Variation in the Composition of "Paris Green," with a Scheme for Its Analysis. By THOMAS B. STILLMAN. *Stevens Indicator*, **15**, 233–240.—The composition of a pure Paris green is given as an aceto-arsenite of copper containing in per cent. CuO, 31.29; As_2O_3, 58.65; $C_2H_4O_2$, 10.06. Adulteration as such is rare in this country, but many samples show an excessive amount of arsenious acid, and the commercial material fails to give uniform results when used as an insecticide. Foreign samples are often found adulterated with barium sulphate, calcium carbonate, lead chromate, or gypsum; but these may be added to alter the shade when the material is designed for use as a pigment. A simple scheme for the analysis of Paris greens, containing the above impurities, is given.

Producing Illuminating Gas and Coke in By-Product Coke-Ovens. By H. O. HOFMAN. *Eng. Min. J.*, **66**, 428–430; 458–460.—A study of the working of ten Semet-Solvay coke-ovens at Halifax, N. S., was made by the author. Since 1897 these ovens have supplied 18 candle-power gas to the city for illuminating purposes, while a fuel gas of 8½ candle-power is also obtained. Of the gas made, 32.26 per cent. is illuminating gas and 67.74 per cent. fuel gas; the latter is used to heat the retorts, and 54.84 per cent. of the total gas made is thus utilized; the remainder is sold for heating gas. Every 24 hours 37 tons (of 2,000 lbs.) are coked and yield 310,000 cubic feet of gas, while 75 per cent. of the weight of the coal charged is obtained as

coke. Each ton of coal also yields about 5 lbs. of ammonia gas and 12 gallons of tar (120 lbs.). An abstract of a report on an Otto-Hoffmann oven, worked at Glassport, Pa., is also included. The coal used was a washed slack from the Dominion Coal Co., Cape Breton. With an average charge of 14591 lbs. of coal containing 9.9 per cent. moisture, the time of coking was 33 hours and 56 minutes. The yield of products per long ton of coal was: coke, 1593.4 lbs. (71.13 per cent.); tar, 75.7 lbs. (3.38 per cent.); ammonia 7.6 lbs. (0.34 per cent.); gas, 10,390 cu. ft. (16.43 per cent.). Of the gas 49.5 per cent. was of 14.7 candle-power, and 50.5 per cent. of 9 candle-power, only available as fuel gas. Carbon disulphide, hydrogen sulphide, gas liquor, and loss, amounted to 8.72 per cent. Numerous tables of analyses of the products and calculations of the heating value of the gas, coal, and coke are given. It is determined that 10.9 per cent. of the calorific value of the coal is consumed in the coking operation. It is shown that the production of illuminating and fuel gas and coke in these ovens rests on a sound theoretical and economic basis.

The Le Sueur Process for the Electrolytic Production of Sodium Hydroxide and Chlorine. By Chas. L. Parsons. *J. Am. Chem. Soc.*, **20**, 868–878.—A short history of the original process is given in which it is shown that some of the criticisms made by Lunge and others are unfounded. A detailed description of the process as carried on at Rumford Falls, Me., follows, in which it appears that the original apparatus has been greatly modified, although the essential features of the process are said to be unaltered. The chief difficulty has always been the diffusion of the caustic solution into the anode compartment. This is combatted by adding hydrochloric acid to the anode compartment, thus decomposing any hypochlorite formed. The amount of acid required is, by the table given, somewhat less than one-sixth of the total weight of salt decomposed. A sketch and a description of the improved cell are given, together with a discussion of the practical working and cost of the process.

Sulphuric Acid and the By-products from Iron Pyrites. By R. G. Ewer. *J. Assoc. Eng. Soc.*, **21**, 160–171.—After a historical sketch of the sulphuric acid industry, tracing the improvements down to the present, the author describes a modern plant, showing a plan and details of a set of chambers of his own design. The process described shows the working of Spanish pyrites, with recovery of copper, silver, and gold and utilization of the iron oxides by blast-furnaces.

Turf Briquettes in Germany. By John E. Kehl. *U. S. Consular Rep.*, 59, 98.—The preparation of this new fuel is de-

scribed briefly, and the success of the new venture predicted. The turf (peat) is carried directly from the bog to a breaker from which it goes to a steam dryer, and is thus obtained as a fine dry dust. This is heavily pressed to form briquettes, which furnish a cheap, clean, and easily handled fuel.

Refining Petroleum with Silicate of Sodium. By R. P. Rothwell. *Eng. Min. J.*, 66, 338.—This article is in the main a condensed statement of the proposition of J. R. Michler to substitute sodium silicate solution for caustic soda in neutralizing the excess of acid left in heavy petroleum oils after the removal of the acid tar. The separation of the silicic acid is claimed to decolorize the oil, as well as to cause the sludge to settle quickly.

Colored Glazes. By S. Geysbeck. *Brick*, 9, 66.—This is a popular article in which is explained the causes of "crazing" and "shivering" in glazes for pottery. Methods of modifying the glazes to overcome these difficulties are given.

Analyses of Commercial Fertilizers. *Agr. Expt. Sta. Bull. Me., No.* 38; *N. J., No.* 124; *Ark., No.* 47; *Wis., No.* 66; *N. Y., No.* 129; *Md., No.* 52; *Miss., No.* 48; *W. Va., No.* 51; *Conn. 21st Ann. Rep., Pt. II; Cal. Ann. Rep., 1895–1897; Wis. 15th Ann. Rep.*; *W. Va. Special Bull., May 1, 1898.*

Crude Caustic Soda Sold in the Market as Caustic Potash. By Carl E. Smith. *Am. J. Pharm.*, 70, 392–398.—In the course of an investigation of the purity of commercial caustic potash, the author found five samples that were nothing else than caustic soda. It is supposed that they represent the supply furnished to grocers and other consumers who are not expected to test their purchases. The products were of good appearance, and might easily deceive their purchasers. Simple methods of testing crude alkali for sodium and potassium, and also quantitative methods for estimating soda and potash, caustic and carbonate, chlorides, sulphates, and silica in crude alkali, are given. The sensitiveness of sodium cobaltic nitrite as a test for potassium was also determined. A solution containing 0.2 per cent. of potassium hydrate showed turbidity in four minutes, but a weaker solution failed to react after many hours.

Sodium Aluminate as a Means for the Removal of Lime and Suspended Matter from Water for Use in Boilers. By Chas. F. Mabery and Edwin B. Baltzley. *J. Am. Chem. Soc.*, 21, 23–27.—The authors first studied a method of making sodium aluminate, which consisted in adding sodium hydroxide to aluminum sulphate solution of known strength. The solution of sodium aluminate so formed was then added in definite quan-

tity to the water to be purified. The reactions involved in the precipitation are:

$$CaH_2(CO_3)_2+Al_2O_4Na_2+H_2O=CaCO_3+2Al(OH)_3+Na_2CO_3,$$

and $$CaSO_4+Na_2CO_3=CaCO_3+Na_2SO_4.$$

Seven different waters were tested by this method and also by sodium hydroxide alone, but in each case the latter removed only about one-half the quantity of lime that was thrown ont by the aluminate. The precipitated alumina also removed suspended matter most completely.

Theory and Practice of Asphalt Mixtures. By A. W. Dow. *Am. Gas-Light J.*, **69**, 862–863.—In testing asphalt for paving, it is often true that the investigator overlooks the physical laws involved, especially those relating to the attraction and adhesion of liquids to solids. Asphalt cement is properly a liquid, and the author showed by a simple experiment that one used in a Washington pavement flowed perceptibly at temperatures of 26°, 75°, and 140° F. A smooth block of asphalt was placed directly over a small hole in a board, and kept at these temperatures for some time. The amount of flow of the asphalt into the hole was measured. The hardness of a pavement mixture is largely dependent on the character of the sand used, very fine, sharp sand forming a much harder mass than coarse sand whose grains were rounded. With rounded grains it was found possible to make a very soft pavement mixture from asphalt which yielded a very hard mass with sharp sand.

Tanning Leather with the Aid of Electrolysis. By Chas. F. Mabery and K. L. Landgrebe. *Proc. Am. Assoc. Adv. Sci., 1898; Abstract Leather Manufacturer*, **9**, 138–139.—Early attempts to apply electric currents to tanning date back to 1849 and 1883. The purpose of this investigation was to study the influence of the current on the chemical change and in hastening the process. The action of sodium sulphide as a depilatory was also studied. Samples of sheep, calf, and steer hides were treated in a bath made by mixing one liter of sodium sulphide solution containing 50 grams of the salt with four liters of lime water. After twenty minutes' agitation, the strongly alkaline bath reduced the hair to a pulp, which was easily scraped off, leaving the skin, after washing, ready for the tan. No bate was necessary, and the skin was soft and plump. This prepared skin was placed in a bark extract liquor between carbon plates and subjected to currents varying from three to six amperes, the potential difference varying from six to twelve volts, according to the strength of the tannin solution. A current of air was blown into the bath for agitation. A solution of 240 grams oak extract in three liters of water, with a current of 3.5 amperes

(six volts potential), tanned the skin samples completely in 1.5 days. A similar experiment without electricity required six days to tan the skins. The current is supposed to assist in the intimate contact between the inner hide substance and oxygen, and also in precipitating coloring-matter, leaving only a clear tannin solution to permeate the skin. The determination of nitrogen in the hide substance shows that the hydrogen liberated exerts some action on the nitrogenous bodies, probably forming ammonia. The proportion of nitrogen in dry and fat-free hide from the same animals is constant; hence this enables the proportion of tannin taken up by the hide substance to be calculated. A table of nitrogen determinations in sheep and calf skins, with and without electrical tannage, is given, showing that nitrogen is removed in the electric bath.

BIOLOGICAL CHEMISTRY.

A. G. WOODMAN, REVIEWER.

A Chemico-Physiological Study of Certain Derivatives of the Proteids. BY R. H. CHITTENDEN, LAFAYETTE B. MENDEL, AND YANDELL HENDERSON. *Am. J. Phys.*, **2**, 142–181.—In the first part of their paper the authors have recorded the results of a study of the physiological effect of a number of cleavage products of proteids, observations having been made as to their influence on blood pressure, on blood coagulation, on lymph flow, flow of urine, and on the apparent immunity conferred upon animals by an intravenous injection of propeptone against subsequent injections of the same substance. The second part of the paper is devoted to a description of the method of preparation of the proteid derivatives used and to a presentation of analyses of (1) antipeptone, which was formed by the action of trypsin on pure antialbumid and was dried at 110° C.; (2) of deuterogelatose, formed by the action of trypsin on gelatine and dried at 105° C. to constant weight; and (3) of the gelatine-peptone separated from the deuterogelatose by ammonium sulphate.

The Effect of Aqueous Solutions upon the Germination of Fungus Spores. BY F. L. STEVENS. *Botanical Gazette*, **26**, 377–406.—In order to determine the strengths of various solutions which just suffice to prevent the growth of fungus spores, the author has made cultures of various fungi in salt solutions of varying degrees of dilution, using the van Tieghem hanging-drop method. Of the salts used, mercuric chloride had the most marked toxic effect, while potassium cyanide was remarkably weak, although it was found that various fungi differ in their resistance to poisons, and that the limits of resistance even

vary in the same species. The cathions Hg, H, and Cu, and the anions CN, CrO_4, Cr_2O_7 and OH are poisonous, while the halogen ions are not poisonous. In general, the results were found to be in accord with the dissociation theory.

The Physiological Action of Certain Plasmolyzing Agents. By Rodney H. True. *Botanical Gazette*, **26**, 407–416.—The author has studied in the case of spirogyra the physiological action of the substances most used as plasmolyzing agents, cane-sugar, glycerine, sodium chloride and potassium nitrate. He is of the opinion that all sodium and potassium salts injure spirogyra through their chemical and not their osmotic properties.

The Proteids of Cream. By E. F. Ladd. *J. Am. Chem. Soc.*, **20**, 858–860.—The proteids of cream were divided into four groups, casein, albumen, albumoses, and peptones; the first group being precipitated by saturated alum solution, the second by boiling, the third by zinc sulphate, and the fourth by 80 per cent. alcohol. The analyses made show that no marked change took place in the proteids during the ripening of the cream.

Composition of Ohio Wines. By Albert W. Smith and Norman Parks. *J. Am. Chem. Soc.*, **20**, 878–882.—The authors have analyzed twelve samples of wine of known purity and a number purchased in the open market. They find that in general their results do not differ much from published analyses of pure European wines from similar grapes, except in the percentages of glycerol and of ash, which are noticeably lower.

The Normal Chlorine of the Water Supplies of Jamaica. By Ellen H. Richards and Arthur T. Hopkins. *Tech. Quart.*, **11**, 227–240.—From the results of analysis of seventy-six samples the authors have drawn a chart of the normal chlorine for the island of Jamaica giving the isochlors for 2.0, 1.0, 0.9, 0.8, 0.5 and 0.3 parts per hundred thousand. It has been found in general that the isochlors follow the coast line, being modified, however, by the excessive precipitation and evaporation which causes varying "dilution and concentration of chlorine." The fact that the interior of the island is but sparsely inhabited has made it possible to prepare a chart which is probably fairly accurate even though so few samples were analyzed.

Concentrated Feed Stuffs. By Joseph B. Lindsey. *Hatch Expt. Sta. Mass. Agr. Coll., Bull.* **56**, 1–24. **Feeds Rich in Protein.** By Edward B. Voorhees. *N. J. Agr. Expt. Sta., Bull.* **131**, 1–14.—These two bulletins contain the results of determinations of water, protein, and fat in various commercial feeding materials, such as cottonseed meal, gluten meal, wheat middlings, etc.

Commercial Fertilizers. *N. Y. Agr. Expt. Sta. Bull.* 145, 49–149; *Me. Agr. Expt. Sta. Bull.* 45, 1–24; *N. J. Agr. Expt. Sta. Bull.* 132, 1–61.

Baking Powders. *N. C. Agr. Expt. Sta. Bull.* 155, 51–56.

The Oil of Corn. By C. G. Hopkins. *J. Am. Chem. Soc.*, 20, 948–961.—As the result of a quite thorough examination of corn oil obtained from various sources the author considers its percentage composition to be as follows: cholesterol, 1.37; lecithin, 1.49; stearin(?), 3.66; olein, 44.85; linolin, 48.19; total, 99.56.

Crystals of Sodium Chloride in Fluid Extract of Yerba Reuma and a Proximate Analysis of this Plant. By Lyman F. Kebler. *Am. J. Pharm.*, 71, 23–25.—The discovery of cubical crystals resembling salt in a fluid extract of Yerba Reuma about fifteen years old led the author to make a proximate analysis of the plant, following Dragendorff's scheme in the main. The most striking result obtained was the high percentage of ash and chlorides, amounting in one case to 34.12 per cent. of ash and 17.42 per cent. of chlorides calculated to sodium chloride.

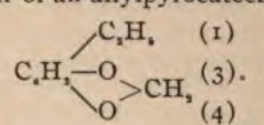
A Report of Progress of Investigations in the Chemistry of Wheat. By G. L. Teller. *Ark. Agr. Expt. Sta. Bull.* 53, 53–80.—In the course of this investigation analyses have been made of wheat gathered on each of forty-two consecutive days from the time of the setting up of the grain. The author finds a marked change in the relative proportion of the nitrogenous constituents at different periods of growth. The gliadin was found to increase largely from the earliest cutting until ripening, while the glutenin and amides decreased. The proportion of ash, amides, fats, fiber, dextrins and pentosans in the dry matter of the grain gradually decreased from the earliest stages. A more or less rapid decrease was also noted in the proportion of sucrose and of reducing sugar, while the proportion of starch rapidly increased up to a week before ripening. The proportion of total proteids in the dry matter steadily decreased up to a week before ripening and then gradually increased. The nitrogen compounds in the ripe grain were present in about the following proportions: amides, 1; edestin and leucosin, 3.5; glutenin, 10; gliadin, 16. The author also brings forward experimental evidence that the proteid designated "Proteose" by Osborne and Voorhees (*Am. Chem. J.*, 15, 468) is gliadin.

The Chemical Composition of the Carcasses of Pigs. By H. W. Wiley and Others. *U. S. Dept. Agr., Div. of Chem., Bull.* 53, 1–80.—This bulletin contains the results of analyses of

the carcasses of eight breeds of American pigs, which had been cut up according to the prevailing method for the American market. In the samples, which were prepared with great care, the following determinations were made: Water, fat, ash, total nitrogen, nitrogen insoluble in hot water, nitrogen soluble in hot water but precipitated by bromine, and lecithin. The analytical results are given in a set of fifty-six tables, which are followed by a discussion. The bulletin also contains an abstract of the literature relating to the separation of flesh bases from other nitrogenous bodies.

An Active Principle in Millet Hay. By E. F. Ladd. *Am. Chem. J.*, **20**, 861–866.—The purpose of this work was to determine whether millet hay contained an extractive principle capable of producing the physiological disturbances that have followed the feeding of it to horses. The ground millet was extracted with petroleum ether and with ordinary ether without obtaining any unusual active principle. Tests made on the aqueous solution of the alcoholic extract, however, indicated the presence of some alkaloid or glucoside. From this aqueous solution, acidified with sulphuric acid, benzine extracted a light-yellow oily liquid, which, in some of its properties, resembled the glucoside *daphnin*, $C_{21}H_{24}O_{10}$, but differed from it in some respects. The physiological effect of this substance upon animals was found to be similar to that of the millet, but more marked.

The Chemistry of Sassafras. By Clemens Kleber. *Am. J. Pharm.*, **71**, 27–32.—The chemistry of sassafras consists principally of the chemistry of its essential oils. The principal ingredient of the oil obtained from the bark of the root, which is what is ordinarily known as oil of sassafras, is safrol. This is the methylene ether of an allylpyrocatechin:



When oxidized this yields piperonal, and by further oxidation piperonylic acid. When safrol is boiled with alcoholic potash its allyl group is transformed into the isomeric propenyl group ($CH_3.CH:CH.$) thus forming isosafrol. The other constituents, present in much smaller quantity, are pinene, phellandrene, camphor, eugenol and cadinene (?). The oil of sassafras-leaves contains also considerable amounts of citral and geraniol as well as linalool, these last two alcohols being present also in the form of their acetic and valerianic esters. In the highest boiling, part is also a paraffin-like substance melting at 58° C.

Analysis of the Root of Hydrangea Paniculata, Variety Grandiflora. By August G. Luebert. *Am. J. Pharm.*, 70, 550–552.—The author has made a proximate analysis of the root of this plant, following Dragendorff's method of analysis. From the alcoholic and ethereal extracts was obtained a crystalline body melting at 178° C. The reactions of this substance indicate that it is not the *hydrangin* found in the closely allied species, *Hydrangea arborescens*, and the author proposes for it the name *parahydrangin*. The amounts of other constituents contained in the root are also given.

Note on the Inversion of Cane Sugar in Official Syrups. By Louis Kahlenberg. *Pharm. Rev.*, 17, 10–12.—A critical review of an article on this subject by F. W. Haussman (*Am. J. Pharm.*, 70, 585).

Notes on Two Oils Containing Pulegone. Reported by Edward Kremers. *Pharm. Rev.*, 16, 412-417. **I. Mentha Canadensis L.** By Florence M. Gage.—The oil obtained by distillation of the fresh herb was examined. Its sp. gr. at 20° was 0.935, and it rotated the plane of polarized light 16°11′ to the right. The characteristic odor for carvacrol was obtained by Flückiger's reaction. By adding amyl nitrite and a trace of hydrochloric acid to the petroleum ether solution of the oil, crystals of nitrosopulegone melting at 79° were obtained. Crystals of pulegone oxime were also obtained corresponding to those from pennyroyal oil. **II. Pycnanthemum Lanceolatum Pursh.** By F. W. Alden.—The author has distilled both green and dry samples of the herb and in each case obtained a test for carvacrol. Using petroleum ether as a solvent, crystalline pulegone oxime was obtained without difficulty according to the method of Beckmann and Pleissner by the action of hydroxylamine hydrochloride and sodium bicarbonate on the oil. The crystals melted at 151°, and after solidification and cooling, the oxime melted at 117°–118°.

G. W. Rolfe, Reviewer.

Glycollic Acid: One of the Acids of Sugar Cane. By Edmund C. Shorey. *J. Am. Chem. Soc.*, 21, 45–50.—The author has obtained glycollic acid from Hawaiian cane-juice in quantities amounting to from seventy-five to eighty per cent. of the total acidity of the juice. He carefully differentiates this acid from malic and aconitic acids, and shows that his results are characteristic of glycollic acid alone. The possible bearing on sugar manufacture of the presence of this acid is also considered. The author believes it may be responsible for much of the caramel formed in molasses products as well as for the foaming of molasses massecuites in cars. The relation of the subject to the chemis-

try of the life processes of the growing cane is most interesting.

Light a Factor in Sugar Production. By H. A. Weber. *J. Am. Chem. Soc.*, **21**, 53–59.—Much evidence, taken from the history of beet and sorghum culture in this country, has been collected by the author to demonstrate that the sugar content of the plant is dependent on the amount of direct sunlight received; hence, this should be an important consideration in deciding upon the most favorable climatic conditions for beet culture.

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REVIEWERS: Analytical Chemistry, H. P. Talbot and W. H. Walker. Biological Chemistry, A. G. Woodman; Carbohydrates, G. W. Rolfe; General Chemistry, A. A. Noyes; Geological and Mineralogical Chem; istry, W. O. Crosby; Inorganic Chemistry, Henry Fay; Metallurgica-Chemistry and Assaying, H. O. Hofman; Organic Chemistry, J. F. Norl ris; Physical Chemistry, H. M. Goodwin; Sanitary Chemistry, E. H-Richards; Technical Chemistry, A. H. Gill and F. H. Thorp.

INORGANIC CHEMISTRY.

HENRY FAY, REVIEWER.

Presidential Address. BY WOLCOTT GIBBS. *Proc. Am. Assoc. Advancement Sci.*, 1898, 1–16. *Science*, **8**, 233–243.—The author attempts to work out the theoretical relations existing between the complex derivatives of molybdic and tungstic acids with the acids of silicon and phosphorus.

On Some Relations among the Hydrates of the Metallic Nitrates. BY J. H. KASTLE. *Am. Chem. J.*, **20**, 814–819.—The author has found that practically all of the salts of nitric acid may be referred to one of the hypothetical nitric acids, and that the nitrates can be grouped under five general classes. The first class, which includes all of the anhydrous nitrates, is regarded as an addition-product of the anhydride of nitric acid and the metallic oxide, $M^{I}_2O+N_2O_5 = 2M^{I}NO_3$. The second class includes a few nitrates, $HgNO_3.H_2O$ and $Th(NO_3)_4.4H_2O$, which are formed by the addition of ordinary nitric acid to a metallic base $M(OH)+HNO_3=MNO_3.H_2O$. To the third class belong a large number of nitrates of the bivalent and trivalent metals which are addition products of ortho-nitric acid and the metallic base derived as follows: $M^{II}(OH)_2+2H_3NO_4=M^{III}(NO_3)_2.4H_2O$; $M^{III}(OH)_3+3H_3NO_4=M^{III}(NO_3)_3.6H_2O$. Examples of this class are $Ca(NO_3)_2.4H_2O$, $Fe(NO_3)_3.6H_2O$, and a large number of double nitrates of which $2Ce(NO_3)_3.3Co(NO_3)_2.24H_2O$ is a type. The fourth class is formed by the addition of a base to the acid H_5NO_6, as $M^{II}(OH)_2 + 2H_5NO_6 = M^{II}(NO_3)_2.6H_2O$, $M^{III}(OH)_3 + 3H_5NO_6 = M^{III}(NO_3)_3.9H_2O$, and $M^{IV}(OH)_4 + 4H_5NO_6 = M^{IV}(NO_3)_4.12H_2O$. By the addition of pyronitric acid to a metallic

base the fifth class is formed : $M(OH)_2 + H_4N_2O_7 = M^{II}(NO_3)_2 . 3H_2O$ of which $Cu(NO_3)_2.3H_2O$ is an example. Including a number of cases of doubtful composition, 75 per cent. of all the normal nitrates described fall under one of these five classes. Most of the basic nitrates may also be classed under these headings as salts of some of the hypothetical nitric acids.

Liquid Ammonia as a Solvent. By E. C. Franklin and C. A. Kraus. *Am. Chem. J.*, **20**, 820–836.—The authors have extended the work of Gore, Weyl, and Seeley on the solubility of various inorganic and organic substances in ammonia. Liquid ammonia was drawn off into a vacuum-jacketed tube and the substance to be tested was introduced into this tube in small quantity at a time and in case the substance was a solid, in the form of fine powder. Where there was any doubt about the solubility a measurement of the electrical conductivity was made. Tables are given which show the solubility of 157 inorganic salts and 250 organic substances.

Metathetic Reactions between Certain Salts in Solution in Liquid Ammonia. By E. C. Franklin and C. A. Kraus. *Am. Chem. J.*, **21**, 1–8.—On account of the close relationship between liquid ammonia and water in solvent power, and in the power of dissociating many salts, it was supposed that metathetic reactions would take place in liquid ammonia as in water. This has been shown to be true. Sixteen nitrates were used to furnish the metallic ions ; and the sulphide, chloride, bromide, iodide, chromate, and borate of ammonia were used as precipitants. The tests were made by bringing the nitrates and the precipitants together in small vacuum-jacketed tubes and observing whether or not a precipitate was formed. Using ammonium chloride as precipitant no precipitates were produced in solutions of sodium and mercuric nitrates ; and from solutions of lithium, potassium, lead, silver, and copper, precipitates were produced only in concentrated solutions ; other nitrates gave precipitates at once. With ammonium bromide the results were the same except that here in addition potassium gave no precipitate and the other precipitations took place more slowly. Ammonium iodide produced precipitations only in solutions of strontium and barium salts. All the metals tested, with the exception of the alkalies, precipitated with ammonium sulphide. Judging from the color only a few of these substances were identical with the sulphides produced in water solution. The magnesium precipitate was found to be a double salt, $2MgS.(NH_4)_2S.xNH_3$, which evolved ammonia and hydrogen sulphide in the air. Ammonium chromate produces precipitates with all metals tested except lithium and sodium ; ammonium borate acts similarly with the exception that the potassium salt is soluble.

On the Solubility of Argentic Bromide and Chloride in Solutions of Sodic Thiosulphate. By Theodore William Richards and Henry Burnell Faber. *Am. Chem. J.*, **21**, 167–172.—The authors have examined the solubility of silver bromide and chloride in sodium thiosulphate by agitating an excess of the pure silver salts with solutions of varying strength of the thiosulphate. After thorough agitation 5 cc. portions were drawn off and analyzed for silver. With increasing strength of the thiosulphate solutions the quantity of silver salt going into solution increased more rapidly than the increase in the quantity of thiosulphate used. The molecular ratio of the sodium thiosulphate to the dissolved salts at 35° C. for 200 grams of the crystallized salt to the liter of water was 1 : 0.78 for silver chloride and 1 : 0.52 for silver bromide. Evidence for the existence of a complex ion in such solutions was obtained by observing the change in the freezing-point ; it was found that by the addition of silver bromide the freezing-point was *raised* indicating the formation of a complex salt.

A New Gas. By Charles F. Brush. *J. Am. Chem. Soc.*, **20**, 899–912.—During an investigation of the heat conductivity of various gases at extremely low pressures, it was found that gases were evolved from the glass on heating, which were only partly reabsorbed on cooling. Supposing the gas to come from the surface, some powdered glass was placed in the tube, and from this the gas seemed to be more freely evolved. On exposure to the air more of the gas was absorbed by the glass. On slight diminution of pressure the gas begins to come off, and the amount rapidly increases with the diminishing pressure. It is readily absorbed by soda-lime and phosphorus pentoxide. The heat conductivity at a pressure of 0.96 millionths of an atmosphere was found to be twenty times as great as that of hydrogen, and that of the pure gas would be 100 times that of hydrogen. If the inference is correct that the heat conductivity and the molecular velocity of gases are directly related, then the molecular velocity of the new gas is also one hundred times that of hydrogen. From this value of the molecular velocity, the density was found to be 0.0001, and the molecular weight, 0.0002. The author suggests that at anything like this molecular velocity, it would be quite impossible for a gas to remain in the atmosphere *unless the space above also contained it*, and therefore that the gas must fill all celestial space. On this assumption he has named the gas "etherion," and suggests that it may have some of the properties of the ether of the physicist.—Various investigators, notably Crookes, have recently claimed that all the phenomena described by Brush can be explained by the presence of a small quantity of water vapor in his apparatus.

Commercial Iron Silicides with a High Percentage of Silicon: Their Properties, Manufacture, and Uses. By G. de Chalmot. *J. Am. Chem. Soc.*, **21**, 59–66.—The author has produced in the electric furnace iron silicides containing from twenty-five to fifty per cent. of silicon and probably consisting of the two compounds $FeSi_2$ and Fe_2Si_3. These silicides are crystalline, white or gray, hard and brittle, unalterable in the air, and can be cast well with sharp outlines and corners. These alloys are recommended for castings, on account of the smooth finish and high luster they are capable of taking; for anodes for electrolysis in aqueous baths; and for abrasives. Their manufacture is carried out by heating iron ore, river sand, and coke, in a special form of electric furnace.

The Preparation of Zirconium Nitrides. By J. Merritt Matthews. *J. Am. Chem. Soc.*, **20**, 843–846.—The compound $ZrCl_4.8NH_3$ heated in a current of nitrogen decomposes and leaves as a gray residue the nitride Zr_3N_4. By heating zirconium tetrachloride in ammonia gas there is decomposition with the formation of the nitride Zr_2N_3.

Method of Preparing a Strictly Neutral Ammonium Citrate Solution. By A. D. Cook. *J. Am. Chem. Soc.*, **20**, 585–586.—The author recommends stirring the citric acid solution after adding ammonia, the heat of neutralization being sufficient to drive off the excess of ammonia.

On the Segregation of Carbon in a Piece of Boiler Plate. By Henry Fay and Henry P. Talbot. *J. Am. Chem. Soc.*, **20**, 614–617.—The authors have examined a piece of boiler-plate steel which, after having been twice annealed, cracked on flanging. On polishing and etching the surface, it was found that the steel was highly crystalline, and that the crystalline layer extended only part way into the plate on either side. Microscopical examination showed the carbon to be much segregated, and analysis of the borings taken from different parts of the plate varied from 0.03 to 0.156 per cent. of carbon. The probable cause of the brittleness was due to the annealing which was done at a temperature, 600°–750° C., at which granulation of mild steel takes place, as has been shown by the experiments of Stead.

ORGANIC CHEMISTRY.

J. F. Norris, Reviewer.

On Some Double Halides of Mercury. By J. N. Swan. *Am. Chem. J.*, **20**, 613–633.—The double chlorides of mercury with aniline and the toluidines were prepared and studied. Aniline, *o*-toluidine, and *p*-toluidine gave salts of the composition, $2HgCl_2.BHCl$, $HgCl_2.BHCl$, and $HgCl_2.2BHCl$ where B repre-

sents the base. With *p*-toluidine but one salt was obtained which had the formula $HgCl_2.BHCl$. A mixed double halide of *o*-toluidine, $HgBr_2.BHCl$ and the following inorganic salts were also prepared : $3HgCl_2.MgCl_2.6H_2O$, $3HgCl_2.SrCl_2.XH_2O$, $3HgCl_2.BaCl_2.8H_2O$.

The Double Halides of Tin with Aniline and the Toluidines. By Robert L. Slagle. *Am. Chem. J.*, **20**, 633–646.—A systematic search for the possible double chlorides of tin with aniline and the toluidines led to the preparation of the following salts which are fully described : With aniline, $SnCl_2.BHCl.H_2O$, $SnCl_2.2BHCl$, $SnCl_4.2BHCl$, and $SnCl_4.2BHCl.3H_2O$; with *o*-toluidine, $SnCl_2.BHCl.\frac{1}{2}H_2O$, $SnCl_4.3BHCl.2H_2O$; with *m*-toluidine, $SnCl_2.BHCl.\frac{1}{2}H_2O$, $SnCl_4.2BHCl.H_2O$; and with *p*-toluidine $SnCl_2.BHCl.\frac{1}{2}H_2O$, $SnCl_2.2BHCl$, $SnCl_4.2BHCl.H_2O$.

On Double Halides of Zinc with Aniline and the Toluidines. By Daniel Base. *Am. Chem. J.*, **20**, 646–664.—The author gives a complete list of all the double halides of zinc with organic and inorganic bases which have been described. A study of the double chlorides of zinc and ammonium showed that but two salts are possible although eight have been described. These salts have the composition $ZnCl_2.2NH_4Cl$ and $ZnCl_2.3NH_4Cl$. A careful study of the possible double chlorides and bromides of zinc with aniline and the toluidines resulted in the formation of the following salts : With aniline, $ZnCl_2.2BHCl.H_2O$, $ZnCl_2.3BHCl.2H_2O$, $ZnBr_2.2BHBr.H_2O$; with *o*-toluidine, $ZnCl_2.2BHCl.2H_2O$, $ZnBr_2.2BHBr.H_2O$; with *m*-toluidine, $ZnCl_2.2BHCl$, $ZnCl_2.3BHCl$, $ZnBr_2.2BHBr.2H_2O$, $ZnBr_2.3BHBr$; and with *p*-toluidine, $ZnCl_2.2BHCl$, $ZnCl_2.3BHCl$, $ZnBr_2.2BHBr.H_2O$.

Sulphonation of the Paraffins. By R. A. Worstall. *Am. Chem. J.*, **20**, 664–675.—The normal paraffins hexane, heptane, and octane are readily sulphonated when they are heated with fuming sulphuric acid in an open flask with a return-condenser. A yield of 30 to 40 per cent. of the monosulphonic acid was obtained when successive portions of the acid were used and the temperature was kept at the boiling point of the hydrocarbon. When the vapors of sulphur trioxide are passed through the boiling hydrocarbons disulphonic acids are produced. The yield of the latter was about 40 per cent. of the theoretical. The mono- and disulphonic acids are thick sirups which form barium and lead salts, which are very soluble in water and deliquesce rapidly.

The Formation of Hydrazides by the Action of Phenylhydrazine upon Organic Acids in the Cold. By Virgil L. Leighton.

Am. Chem. J., **20**, 676–679.—Acetylphenylhydrazide was formed when a solution of phenylhydrazine acetate in acetic acid was allowed to stand four days. The formation of hydrazides from the phenylhydrazine salts of acids dissolved in the smallest quantity of the respective acid was shown to be a general reaction by the preparation of the hydrazides of formic, acetic, propionic, isobutyric, isohexylic, and heptylic acids.

Aliphatic Sulphonic Acids: II. Ethylenesulphonic Acids. By Elmer P. Kohler. *Am. Chem. J.*, **20**, 680–695.—Ethylenesulphonic acid was prepared by decomposing 1,2-ethanedisulphone chloride with boiling water, by distilling 1,2-bromethanesulphone chloride under an increased pressure, and by heating the potassium salt of the acetic ester of isethionic acid at 185°. The acid forms well-crystallized ammonium, potassium, sodium, barium, and lead salts. The chloride of the acid prepared by treating the potassium salt suspended in chloroform with phosphorus pentachloride can be distilled under diminished pressure. Ethylenesulphonic acid is oxidized readily, the products being carbon dioxide, sulphuric acid, and water. Reduction is effected with difficulty: sodium amalgam in alkaline solution and zinc in acid solution are without effect. When the acid is heated with phosphorus and iodine, ethanesulphonic acid is formed. Ethylenesulphonic acid combines readily with water, especially in the presence of alkali, forming isethionic acid. When heated at 130° with hydrochloric and hydrobromic acids, addition-products are formed in which the halogen atoms are in the 2-position. With bromine, 1,1-bromethylenesulphonic acid is produced, the substitution being rapid and complete even at 0°.

The Ethers of Toluquinoneoxime and their Bearing on the Space Isomerism of Nitrogen. By John L. Bridge and Wm. Conger Morgan. *Am. Chem. J.*, **20**, 761-776.—Toluquinone-*o*-oxime obtained by the action of nitrous acid on *m*-cresol forms well-characterized acetyl, benzoyl, and methyl ethers. The benzoyl ether of toluquinone-*m*-oxime, prepared in the same way from *o*-cresol, was shown to consist of a mixture of two isomeric substances, which were separated by fractional crystallization. The same ethers were obtained from the oxime formed by the action of hydroxylamine on toluquinone, and as no toluquinone-*o*-oxime was formed under these circumstances it seems highly probable that the isomerism is due to the space relation of the oxime group. Isomeric acetyl and methyl derivatives of toluquinone-*m*-oxime were also obtained. The compounds mentioned and a number of their bromine derivatives are described fully.

Camphoric Acid. By William A. Noyes. *Am. Chem. J.*, **20**, 789–814.—By an error in his thermometer the author working with E. B. Harris, was led to think that the oxime of a ketone prepared from cis-campholytic acid (Harris, *this Rev.*, **3**, 12), and the oxime of dimethyl-(1,3)-cyclohexanone (2) made by Kipping (*J. Chem. Soc.*, **67**, 357) were identical. If the oximes were the same cis-campholytic acid would have the structure of Δ^1-tetrahydroxylic acid, $C_6H_7(CH_3)_2(1,3)COOH(2)$ and accordingly the synthesis of the latter acid was attempted. Although the preparation of the xylic acid will probably throw no light on the structure of cis-campholytic acid, the synthesis, which has been carried as far as the preparation of the neighboring xylic acid, is described, as a large number of new compounds has been prepared. The nitrile of the acid was obtained by the diazo reaction from 2-amino-*m*-xylene, but its saponification could not be effected. The xylidine required was obtained from commercial xylidine, in which it is present to the extent of about 2 per cent. An attempt was next made to prepare the xylic acid from dimethylcyclohexanone. In the preparation of the necessary dimethylpimelic acid, the dimethylpentanetetracarboxylic acid obtained as an intermediate product was isolated and found to have properties different from those which had been assigned to it. Dimethylcyclohexanone was prepared from dimethylpimelic acid, but the attempts to convert it into the hexahydroxylic acid through the cyanhydrin or cyanide were unsuccessful. The next method of preparation studied was the conversion of ethylidenediacetacetic ester into a cyclic compound by distillation under diminished pressure with chloroform and subsequent treatment with bromine (Knoevenagel, *Ann. Chem.* (Liebig, **281**, 121). As only dimethyl-(1,3)-phenol-5-methylic-(2) acid, and its ethyl ester were obtained the method was abandoned. Unsuccessful attempts to prepare the xylic from acetobromxylene and acetoiodoxylene led to the preparation of 4-chlor-2-brom-*m*-xylene, 4-aceto-5-brom-1,3-xylene, bromxylic acid, $C_6H_2(CH_3)_2(1,3)COOH(4)Br(5)$, acetoiodoxylene, $C_6H_2(CH_3)_2(1,3)COCH_3(4)I(5)$, iodoxylylglyoxalic acid, $C_6H_2(CH_3)_2$, CO.COOH, iodomethylterephthalic acid, $C_6H_2CH_3(1)(COOH)_2(2,3)I(5)$ and two iodoxylic acids. The preparation of the neighboring xylic acid was finally effected from acetomesitylene. Improved directions for the preparation of mesitylene from acetone are given by which the yield is greatly increased. The mesitylene was converted into the acetyl derivative which, when oxidized, gave a mixture of about equal parts of 2,6-dimethyl terephthalic acid and dimethylphthalic acid. The acid ester of the former acid was converted into the amide, which was changed into an amine by means of sodium hypobromite. The amido group was replaced by iodine, which in turn was removed

by zinc dust and ammonia. The resulting acid was the neighboring xylic acid sought. The author proposes to reduce this acid.

On the Non-existence of Four Methenylphenylparatolyl Amidines. By H. L. Wheeler and T. B. Johnson. *Am. Chem. J.*, **20**, 853–861.—The authors have carefully studied the four methenylphenylparatolyl amidines prepared according to Zwingenberger and Walther (*J. prakt. Chem.*, **57**, 209), and have found that the substances are not pure compounds. By fractional crystallization the amidines were shown to consist of two or more substances. By crystallizing together mixtures of the constituents found, crystals were obtained which had the properties of the amidines described and which formed double platinum salts and picrates agreeing closely in melting-points with those given by Zwingenberger and Walther. The fact that but one methenylphenylparatolyl amidine exists destroys the conclusions of Walther (*J. prakt. Chem.*, **55**, 43; **57**, 229) as to the structure of the anilides. Methenylmethylphenylamide-phenylimidine, $C_6H_5(CH_3)N—CH=NC_6H_5$, was prepared by mixing methylaniline with methylisoformanilide, by adding a mixture of methylaniline and formanilide to an excess of phosphorus trichloride, and by heating methenyldiphenylamidine with an excess of methyl iodide. The compound is a colorless oil, which forms a hydrochloride and a double chloride with gold.

Creatin and Its Separation. By E. F. Ladd and P. B. Bottenfield. *Am. Chem. J.*, **20**, 869–870.—The amount of creatin in ox flesh was determined by the methods of Neubauer, Stradler, and Liebig and was found to be 0.250, 0.234, and 0.215 respectively. The same methods of analysis applied to the flesh of a dog gave 0.242, 0.230, and 0.218 per cent. The authors consider the high results obtained by Neubauer's method the most accurate.

A Double Citrate of Zirconium and Ammonium. By S. H. Harris. *Am. Chem. J.*, **20**, 871–872.—By adding an aqueous solution of ammonium citrate to a solution of zirconium chloride a double salt of the composition $Zr_2(C_6H_5O_7)(NH_4)_3$ was formed as a curdy white precipitate which was very deliquescent when dried.

On the Constitution of the Phenylhydrazones. By Paul C. Freer. *Am. Chem. J.*, **21**, 14–64.—Two possible constitutions can be assigned to the compounds of phenylhydrazine with ketones and aldehydes:

$$(1)\quad \begin{array}{c} R'RHC \\ | \\ R''_2C.C:N.NHC_6H_5 \end{array} \quad \text{and} \quad (2)\quad \begin{array}{c} RR'C \\ \| \\ R''_2C.C.NH.NHC_6H_5. \end{array}$$

When phenylhydrazine reacts with an aldehyde or a ketone there is, in all probability, a direct addition-product formed, which immediately loses water and passes into the hydrazone. This elimination of water could take place in two ways and would yield either a true hydrazone (formula 1) or a hydrazo compound (formula 2). That such addition-products are formed was shown by the fact that ethereal solutions of aldehyde and methylethyl ketone, when cooled to —20° and mixed with phenylhydrazine, gave precipitates which dissolved and changed into hydrazones. The phenylhydrazones can be divided into two classes: those which are readily oxidized in the air and change to non-crystallizable tars with the evolution of gas, such as the phenylhydrazones of acetone, other aliphatic ketones, and acetophenone; and those which are perfectly stable or do not yield oxidation-products, such as the derivatives of aceto-acetic ester, pyruvic acid, and benzophenone. It is concluded that the hydrazones of the first class are probably hydrazo compounds and have the structure represented by formula (2) while those of the second class are true hydrazones (formula 1). This conclusion is justified by the fact that acetone-*p*-bromphenylhydrazone, when carefully subjected to the action of the air, is quantitatively changed to a red explosive azo compound, which is reduced by sodium amalgam to the original hydrazone. The azo compound exhibited the characteristic properties of true azo bodies, forming a crystalline perbromide, which decomposed in the manner typical of such compounds. Since the formation of an azo compound from a true hydrazone by oxidation seems highly improbable, formula (2) must be assigned to acetone-*p*-bromphenylhydrazone. The phenylhydrazone of acetophenone formed derivatives analogous to those described above. The two classes of hydrazones show a marked difference in behavior with benzoyl chloride. Acetonephenylhydrazone, which is readily oxidized to an azo compound, and has the hydrazo structure, readily reacts with benzoyl chloride and forms a product containing two benzoyl radicles, whereas benzophenone, having the hydrazone structure, reacts with difficulty and the resulting compound contains but one benzoyl group. This method of deciding structure can not be applied to the large number of hydrazones which do not react with benzoyl chloride. If the phenylhydrazones are formed by the elimination of water from an addition-product of the ketone and phenylhydrazine, it is possible that one ketone might yield two isomeric derivatives represented by the above formulas. Smith and Ransom (*Am. Chem. J.*, **16**, 108), have proved the existence of two benzoïnphenylhydrazones and considered them to be geometrical isomers. The author's method of study shows that the two substances have different structures. One is readily

oxidized to an azo compound by nitrogen trioxide with which it forms a red crystalline addition-product, which in turn forms a characteristic perbromide. The other, when treated in the same way, gives a white tetrazone. β-Benzoïnphenylhydrazone is converted into an isomeric substance by benzoyl chloride. The two acetaldehydrazones were studied in the same way but the results were not conclusive, since the two compounds change from one form to the other with great readiness. Doubt is thrown upon the structure of the compound prepared by oxidizing acetoaceticesterphenylhydrazone with mercuric oxide. The facts that the compound does not give a perbromide, that it is not reduced to the original hydrazone by sodium amalgam, and that it can be heated above its melting-point without decomposition, show that it is not benzene-azo-β-oxycrotonic ester. Chloraldehyde hydrate and phenylhydrazine yielded a substance of the structure

$$C_6H_5.NH.NH.CH_2.CH : N.NH.C_6H_5.$$

Note on the Action of Liquid Hydriodic Acid on Ethyl Ether. By F. G. Cottrell and Roy Ravone Rogers. *Am. Chem. J.*, **21**, 64–67.—When ether and liquid hydriodic acid were mixed a vigorous reaction took place and water and ethyl iodide were formed. By conducting the experiment in a specially designed piece of apparatus, an almost quantitative yield of ethyl iodide was obtained. This is noteworthy since Silva has shown (*Compt. rend.*, **81**, 323) that with gaseous hydriodic acid alcohol was also formed.

Certain Alkaloidal Periodides and the Volumetric Estimation of Alkaloids as Higher Periodides. By A. B. Prescott and H. M. Gordin. *J. Am. Chem. Soc.*, **20**, 706–728.—By pouring a solution of atropine in dilute hydrochloric acid into a large excess of Wagner's reagent a periodide is precipitated containing nine iodine atoms. Under similar conditions strychnine, brucine, and aconitine give periodides containing seven atoms of iodine, while with morphine the precipitate contains but four atoms of iodine. The authors show that the formation of these perhalides is quantitative, and describe the volumetric estimation of the above alkaloids based on this reaction. Two double iodides of atropine and mercury are also described.

On Tetraphenylmethane. By M. Gomberg. *J. Am. Chem. Soc.*, **20**, 773–780.—Improved directions for the preparation of tetraphenylmethane from triphenylmethanehydrazobenzene are given. A molecular weight determination of the hydrocarbon and an analysis of the tetranitro-derivative furnish further evidence for the composition which has been assigned it. This is also shown by the fact that the nitro-derivative does not

form a sodium salt, whereas dinitrodiphenylmethane and trinitrotriphenylmethane give highly colored sodium compounds.

Hydrazo- and Azo-derivatives of Triphenylmethane. By M. Gomberg and A. Campbell. *J. Am. Chem. Soc.*, **20**, 780–790.—Well-crystallized hydrazo-compounds were formed by treating triphenylbrommethane with a large number of hydrazines. They oxidize in the air and form salts with dry hydrochloric, oxalic, picric, and other acids. The hydrazo-compounds are readily oxidized by amyl nitrite to azo-derivatives, which give off their nitrogen quantitatively when heated.

A Periodide of Triphenylbrommethane. By M. Gomberg. *J. Am. Chem. Soc.*, 790–793.—Triphenylbrommethane unites with iodine in benzene solution and forms a periodide of the composition $(C_6H_5)_3CBr.I_4$, which crystallizes in hollow hexagonal crystals.

Perhalides of Quinoline. By P. F. Trowbridge. *J. Am. Chem. Soc.*, **21**, 66–72.—A large number of perhalides of quinoline containing one, two, and four added halogen atoms are described. Halogen addition-products of the compounds formed by the union of quinoline and methyl chloride, bromide, and iodide were also prepared.

Analysis of Aqueous Alcohol. By Chester B. Curtis. *J. Phys. Chem.*, **2**, 371–375.—The amount of alcohol in an aqueous solution can be estimated by determining the quantity of toluene necessary to cause a cloudiness in the solution. The method can be used only when the solution contains above eighty-five per cent. of alcohol and gives results as accurate as those obtained by the pycnometer test.

The Physical and Chemical Properties of Lithium Benzoate and Lithium Salicylate. By Lyman F. Kebler. *Am. J. Pharm.*, **71**, 57–64.—The properties of samples of lithium salicylate and benzoate, which are on the market, and of the carefully purified salts, are described in detail.

The Electric Current in Organic Chemistry. By Edgar F. Smith. *Proc. Am. Assoc. Advancement Sci.*, *1898*, 179–194.—This paper is a historical address delivered by the author as chairman of the Chemical Section of the Association.

GEOLOGICAL AND MINERALOGICAL CHEMISTRY.

W. O. Crosby, Reviewer.

Notes on North Carolina Minerals. By J. H. Pratt. *J. Elisha Mitchell Sci. Soc.*, **14**, *pt.* 2, 61–83. The notes on four of

the nine minerals considered in this article, wellsite, anorthite, cyanite and zircon, have peen published elsewhere and noticed in this Review. The remaining species are chabazite, anthophyllite, enstatite, enstatite (bronzite), and emerald beryl. The chabazite occurs as minute crystals coating feldspar, hornblende and corundum and intimately associated with the wellsite, in a corundum mine in Clay County. Two analyses are given; and the ratio of Al_2O_3 to the protoxide bases is found to be somewhat below the normal. The anthophyllite, which occurs in dunite rock near Bakersville, was originally described by Penfield in 1890, before the locality was known. A new analysis is given, and Penfield's analysis is quoted for comparison, the two agreeing very closely, and closely approximating the normal composition. The enstatite forms rock masses bordering the dunite of Corundum Hill. The analysis indicates the admixture of 35 per cent. of serpentine and 20.5 per cent. of talc, the pure enstatite forming but 44.5 per cent. of the whole. The bronzite forms with an emerald-green diopside a tough rock (websterite) in the dunite of the Tuckaseegee Valley; and the websterite also varies to a nearly pure bronzite rock. The analysis and physical characters show this to be a very typical bronzite. The emerald beryl occurs in a vein of pegmatite, and is in part of gem quality; but it has not been analyzed. All of the new analyses of the foregoing minerals were made by Chas. Baskerville of the N. C. Geological Survey.

The Origin and Chemical Composition of Petroleum. A SYMPOSIUM. BY S. P. SADTLER, S. F. PECKHAM, DAVID T. DAY, FRANCIS C. PHILLIPS AND CHARLES F. MABERY. *Proc. Am. Phil. Soc.*, **36**, 93–140.—This paper is a valuable summary of our knowledge of petroleum and natural gas, and in a measure of all of the native bitumens. Prof. Sadtler discusses the genesis and chemical relations of petroleum and natural gas; and rejecting all the theories of the inorganic origin of these bodies, and weighing carefully the rival theories of their derivation from animal tissues and from plants, concludes, partly from original experiments with linseed oil, that both the theories of their organic origin are required to explain all the facts. Prof. Peckham's contribution is on the nature and origin of petroleum, setting forth at some length the facts which appear to sustain the distillation theory, which is made to cover all the native bitumens from natural gas to asphaltum. Dr. Day develops a suggestion as to the origin of Pennsylvania petroleum which is a modification of Mac Gonigle's theory that the Pennsylvania oils have been derived by distillation from the underlying Silurian strata, the transfer from the lower to the higher formations, with a notable increase in density and loss of sulphur,

having, according to Day, been accomplished, not by distillation but by an upward filtration through beds of shale. Prof. Phillips discusses and accepts provisionally Mendeléeff's theory that metallic carbides have been produced deep in or below the earth's crust, and that these carbides have been decomposed by steam, giving rise to the various hydrocarbons of oil and gas; and in accordance with this view the author argues strongly against the view that petroleum occurring in the cavities of fossils is indigenous in them. Prof. Mabery, in considering the composition of American petroleum, notes the progress of our knowledge, the difficulty of correlating the composition or specific gravity with the distribution or geological occurrence. Even the high sulphur oils, which some have regarded as peculiar to limestones, are shown to be also very typically developed in sandstones and shales. The importance and feasibility of a general system of classification on the basis of the series of hydrocarbons which constitutes the main body of the crude oils are discussed at some length.

The Genesis of Bitumens, as Related to Chemical Geology. By S. F. PECKHAM. *Proc. Am. Phil. Soc.*, 37, 108–139.—This paper is a sequel to the preceding symposium; but the author contents himself with a very general discussion of the geology of the bitumens and especially of petroleum, and a restatement of the facts supporting the distillation theory of petroleum and natural gas.

M. L. FULLER, REVIEWER.

On Dikes of Felsophyre and Basalt in Paleozoic Rocks in Central Appalachian Virginia. By N. H. DARTON. **Notes on the Petrography.** By ARTHUR KEITH. *Am. J. Sci.*, **156**, 305–315.—A third locality of igneous rocks in the Central Appalachian region has recently been discovered by Mr. Darton. Both basic and acidic dikes are represented, the latter belonging to the granite family and most nearly resembling felsophyre. Petrographic descriptions of both types are given by Mr. Keith, supplemented by an analysis of the felsophyre by W. F. Hillebrand.

Causes of Variation in the Composition of Igneous Rocks. By T. L. WALKER. *Am. J. Sci.*, **156**, 410–415.—A brief review is given of the usual theories of magmatic differentiation. The author considers that none give satisfactory explanations of all the phenomena observed, especially of the excessively basic centers of certain eruptive masses. Attention is called to the fact that certain homogeneous solutions remaining for a long time at constant temperatures become gradually more concentrated in the lower portion, and it is urged by the author that a similar concentration probably occurs in complex silicate mag-

mas, especially when near the temperature of consolidation. The material along the borders solidifies before the differentiation is far advanced, representing the original composition. Differentiation and solidification progress simultaneously, and hence the central portions will have suffered the greatest changes. In the upper horizons of the eruptive there would be an increase in *acidity* towards the center; the middle horizons would show little differentiation, while the lower horizons would show an increase in *basicity* towards the center. These relations are illustrated graphically by a diagram. It is not considered that this is ever a sole cause of differentiation. The ability of gravitation to produce concentration in solutions is denied by some physicists, but is upheld by those who have investigated it most carefully.

On the Associated Minerals of Rhodolite. By W. E. Hidden and J. H. Pratt. *Am. J. Sci.*, **156**, 463–468.—The more common associated minerals of this new variety of garnet are quartz, corundum, pleonaste, gahnite, chromite, iolite, staurolite, monazite, zircon, gold, and sperrylite. The occurrence of each is described and analyses by Chas. Baskerville are given for gahnite and iolite.

Platinum and Iridium in Meteoric Iron. By John M. Davison. *Am. J. Sci.*, **157**, 4.—After treating the Coahuila and Toluca meteoric irons with hydrochloric acid, there remained in each case a fine black residue consisting of irregular or tetragonal crystals of rhabdite, carbon, and some stony matter. Analyses of these sediments showed the presence of both platinum and iridium. From 608.6 grams of Coahuila iron there were obtained 0.014 gram of platinum, and 0.0015 gram of a black powder, probably iridium. The amounts obtained from the Toluca iron were considerably less. Unsuccessful search was made for microscopic diamonds.

Mineralogical Notes: Analyses of Tysonite, Bastnäsite, Prosopite, Jeffersonite, Covellite, Etc. By W. F. Hillebrand. *Am. J. Sci.*, **157**, 51–57.—The analyses of the following minerals were made in the laboratory of the U. S. Geological Survey. 1. Tysonite and bastnäsite. Analyses of fine specimens from Cheyenne Mt., near Pikes Peak, Col., agreed essentially with those of Allen and Comstock. The formulas $R'''F'_3$ for tysonite and $R'''(F',CO''_3)$ for bastnäsite, which in the absence of fluorine determinations have not hitherto been confirmed, are shown to be correct. The analyses show some 40 per cent. of Ce_2O_3 (including ThO_2), with a little less of the La group. 2. Prosopite. A beautiful pale green mineral from Utah, supposed by Kunz to be utahlite, proved on analysis to be prosopite, mixed

with quartz and fluorite (?), and colored by some copper salt. Comparison with Altenberg and Pikes Peak prosopites shows a close agreement except in amounts of F and H_2O, the variation of these two affording further evidence as to their mutual replacement by one another. 3. Jeffersonite. An analysis of a brown mineral from Franklin Furnace, N. J., agrees closely with that of jeffersonite but its physical properties differ from hitherto published data of that mineral. The author considers the analysis chiefly valuable as showing a wide range of composition for the mineral. 4. Analyses are also given for covellite, enargite, and a blue stalactite from Butte, Montana, and a fibrous sulphate corresponding to the empirical formula $(FeMn)_4$-$(ZnMg)_2Al_2(SO_4)_9.65H_2O$ from near Whitehall, Montana.

On the Chemical Composition of Tourmaline. By S. L. Penfield and H. W. Foote. *Am. J. Sci.*, 157, 97–125.—This important mineralogical contribution consists essentially of an elaborate review and critical discussion of the investigations of Rammelsberg, Riggs, Jannasch and Kalb, and others upon the constitution of tourmaline. Two new and carefully executed analyses are given which agree closely with those of previous investigators. Rammelsberg's conclusion that all tourmalines are derived from the acid H_6SiO_5 was based on analyses which the authors have shown to be defective. On applying the necessary corrections, however, the general formula $H_{20}B_2Si_4O_{21}$ may be derived, which agrees with that obtained by Riggs, Jannasch, and Kalb, and the authors. A critical examination of the many published analyses, taken in connection with their own analyses of exceptionally pure specimens, leads the authors to the conclusion that all varieties of tourmaline are to be considered as salts of the acid $H_9Al_3(B.OH)_2Si_4O_{31}$, in which the complex aluminium-borosilicic acid radical exerts a *mass effect* by virtue of which the remaining hydrogens may be replaced by numerous metals of essentially different characters without any pronounced effect on crystalline form. The table of the ratios $R' : R'' : R''' : H$, derived from some 35 analyses, including practically all varieties thus far investigated, shows that although certain prominent types undoubtedly exist, the ratios do not approach closely enough to rational members to give definite formulas.

On the Occurrence of Cubanite at Butte, Montana. By Horace V. Winchell. *Am. Geol.*, 22, 245.—An analysis of a brass-yellow ore of copper gave results agreeing closely with both the theoretical composition and with previous analyses of cubanite.

The Origin of the Archean Igneous Rocks. By N. H. Winchell. *Am. Geol.*, **22**, 299–310. It has been previously assumed that the oldest known rocks were of the acid type, but the author has recently endeavored to show that the ferro-magnesian greenstones may be considered as the existing representatives of the original crust, and that the acid rocks are of a later period. T. Sterry Hunt had previously reached a similar conclusion as to the nature of the primitive crust on chemical grounds, and had explained the minerals of the acid rocks as derived by leaching from the ferro-magnesian types, giving as an example of the process, the occurrence of potash feldspar in geodes, etc., in the Keweenawan diabase. The author holds, on the contrary, that the feldspar is probably a true aqueous deposit of material derived from extraneous sources, and that a more probable view as to the origin of the acid rocks is that they have been derived from the fusion of deeply buried sediments. Several supposed examples of such derivation are described, and the process is suggested as a general explanation of the granites throughout Minnesota. The acid elements, however, and especially the potassium, could not have been derived from the basic greenstones. The conclusion is that for these elements we must look to the atmosphere as it existed upon the original congelation of the crust, and this leads up to the question of the chemical properties and volatility of potassium, and its probable activity under Archean conditions.

On the Dikes in the Vicinity of Portland, Maine. By E. C. E. Lord. *Am. Geol.*, **22**, 335–346.—Both basic and acid types are represented in the dikes of Casco Bay and vicinity, but only the basic varieties are considered in detail. Of these, olivine-diabase-porphyry is represented by 24 dikes, while enstatite-diabase-porphyry and camptonyte are represented by two each. With one exception they have a persistent strike of N. 55° E. Petrographical and mineralogical descriptions are given for each variety and its alteration discussed. Analyses are given for anorthoclase, barkevicitic hornblende, and the enstatite-diabase-porphyry. From the field relations and composition it is concluded that the Casco Bay dikes are genetically related to those of Kennebunkport and Bald Cliff. The similarity in composition to augite-syenite from Norway suggests the possibility that certain of the dikes at least are offshoots of an underlying parental rock of that description. Their age is less than that of the associated pegmatites, and it is conjectured that they are coincident with a period of volcanic activity towards the close of the Devonian, and contemporaneous with the granitic intrusions of Nova Scotia and New Brunswick.

GEOLOGICAL AND MINERALOGICAL CHEMISTRY.

M. L. FULLER, REVIEWER.

Thomsonite and Lintonite from the North Shore of Lake Superior. BY N. H. WINCHELL. *Am. Geol.*, **22**, 347–349.—The paper describes the properties, associations, and localities of both minerals. An analysis of lintonite is given and the reasons (optical) for its separation from mesolite or thomsonite, to which it might be referred on chemical grounds.

Thalite and Bowlingite from the North Shore of Lake Superior. BY N. H. WINCHELL. *Am. Geol.*, **23**, 41–44.—The treatment of the subject is mainly descriptive, but includes a new analysis of thalite.

Chlorastrolite and Zonochlorite from Isle Royale. BY N. H. WINCHELL. *Am. Geol.*, **23**, 116–118.—The paper includes descriptions of both minerals, with an analysis of the former.

On the Occurrence of Quenstedtite near Montpelier, Iowa. BY OTTO KUNTZE. *Am. Geol.*, **23**, 119–121.—The sandstone bed of a small creek is locally incrusted above the water with a dry yellow mineral which on analysis proved to be nearly pure quenstedtite ($Fe_2(SO_4)_3 + 10H_2O$), a mineral previously described by Dana as coming only from Chile. On exposure to direct sunlight it rapidly decomposes and disappears, but under favorable conditions may accumulate to a thickness of 1 or 2 inches during a single summer. The material is derived from the decomposition of fine scales of pyrite, with which the sandstone is filled.

Clay Resources of Missouri. BY H. A. WHEELER. *Eng. Min. J.*, **66**, 426–427.—The paper includes statistics relating to the character, use, output, and price of the clays, with a description of the condition of the industry. Analyses are given for white-ware clays, fire clays, potter's clays, shales, brick clays, and gumbo clays.

The Alkaline Reaction of Some Natural Silicates. BY F. W. CLARKE. *J. Am. Chem. Soc.*, **20**, 739–742.—On adding distilled water containing a very little alcoholic phenolphthalein to samples of certain finely pulverized silicates, including micas, feldspars, zeolites, etc., alkaline reactions were immediately obtained. As would be expected, the colors were most intense in the case of those minerals which in nature are most subject to alteration. Similar results were also obtained from tests upon the common igneous rocks. The rapidity of the action is a striking feature.

Petroleum Inclusions in Quartz Crystals. By Chas. L. Reese. *J. Am. Chem. Soc.*, **20**, 795–797.—Crystals of quartz with petroleum inclusions from Marshall Co., Ala., are described and illustrated. The petroleum was recognized by its fluorescence, odor, and combustibility.

Mineral Resources of Cuba. By Raimundo Cabrera, translated by L. E. Levy. *J. Franklin Inst.*, **146**, 26–41.—Descriptions and analyses are given of the more important ores and economic deposits including asphaltum, phosphate rock, and the ores of gold, silver, lead, copper, iron, and manganese.

The Slate Regions of Pennsylvania. By Mansfield Merriman. *Stone*, **17**, 77–90.—A description is given of each of the principal slate-producing regions, accompanied by tables of statistics relating to the output and properties of the slates. The probable resistance to corrosion by smoke, sulphurous vapors, etc., was tested by treatment for 63 hours in a 2 per cent. solution of $HCl + H_2SO_4$. The results are given in a tabulated form.

The Bayport, Michigan, Quarries. By A. C. Benedict. *Stone*, **17**, 153–164.—The limestone from these quarries is used as road metal, building stone, or burned for lime. Analyses are given for the building stone and lime varieties.

GENERAL AND PHYSICAL CHEMISTRY.

A. A. Noyes, Reviewer.

A Revision of the Atomic Weight of Nickel. II. The Determination of Nickel in Nickelous Bromide. By Theodore William Richards and Allerton Seward Cushman. *Proc. Am. Acad.* **34**, 327–348.—The authors have found that the samples of nickel bromide previously used (see *this Rev.*, **4**, 27) for determining the ratios $NiBr_2 : 2AgBr$ and $NiBr_2 : 2Ag$ contained about 0.1 per cent. of sodium bromide, this contamination having been introduced in the final sublimation of the samples in a porcelain tube. After a fruitless attempt to obtain a pure product by subliming in a platinum-lined tube, the authors decided to make a complete analysis of the slightly impure substance by determining the exact amount of sodium bromide and the amount of nickel present, in the same samples in which the bromine had peen previously estimated. With this end in view it was attempted to precipitate the nickel electrolytically, as had been done by Winkler, but experiments made by dissolving weighed portions of pure spongy nickel and electrolyzing in a platinum dish showed that the weight deposited was always appreciably greater than that of the nickel originally taken (0.2

per cent. greater when the method of Winkler of drying at 50° was followed), probably owing to the inclusion of mother-liquor and of hydrogen. The following method was therefore adopted: the weighed nickel bromide contained in a platinum boat was reduced with moist hydrogen at a comparatively low temperature, the hydrogen replaced by dry air, and the boat weighed; the residue was then digested repeatedly with pure water and the bromine in the filtrates was precipitated and weighed as silver bromide. The possible errors in this procedure were carefully investigated: thus it was shown by rinsing out the cooler parts of the combustion tube with nitric acid that no nickel bromide was lost by volatilization; by exposing the spongy nickel to the air that no oxidation took place; by burning it in air in a combustion tube that no water was produced, and, therefore, that no hydrogen was occluded; and by qualitative analysis of the water extract that it contained nothing but sodium bromide and some nickel dissolved by the action of water on the metal itself. Making proper corrections for the amount of sodium bromide present, the mean values of the atomic weights calculated from the different ratios determined are as follows: 58.703 from $NiBr_2 : 2AgBr$; 58.704 from $NiBr_2 : 2Ag$; and 58.709 from $NiBr_2 : Ni$. As the final value based on all determinations, 58.706 is adopted. The article closes with a criticism of the work of previous investigators on the same subject.

A Revision of the Atomic Weight of Cobalt. II. The Determination of the Cobalt in Cobaltous Bromide. By THEODORE WILLIAM RICHARDS AND GREGORY PAUL BAXTER. *Proc. Am. Acad.*, **34**, 351–369.—This investigation is closely analogous to the one on nickel just reviewed. The cobalt bromide was proved to contain about 0.1 per cent. of impurity by reducing it in hydrogen, leaching with water, evaporating, and weighing the residue, this being admissible in this case since the cobalt dissolved by the water is almost all precipitated in the cobaltic form during the evaporation by the oxidizing action of the air. The residue was found to consist mainly but not wholly of sodium bromide. The final values of the atomic weights derived from each of the ratios determined are: $CoBr_2 : 2AgBr$, 58.995; $CoBr_2 : 2Ag$, 58.987; $CoBr_2 : Co$, 58.998, the final average adopted being 58.995. At the close of the article various criticisms made by Winkler are answered.

Sixth Annual Report of the Committee on Atomic Weights. Results Published in 1898. By F. W. CLARKE. *J. Am. Chem. Soc.*, **21**, 200–214.—The following is a summary of the results published in 1898, the values given by the author in his last year's table being appended in parentheses.

Oxygen, Keiser	15.880	(15.879)
Nitrogen, Dean	14.055	(14.04)
Boron, Armitage	10.959 10.928	(10.95)
Zinc, Morse and Arbuckle	65.457	(65.41)
Cadmium, Morse and Arbuckle	112.377	(111.95)
Selenium, Lenher	79.314	(79.02)
Tellurium, Metzner	127.9	(127.49)
" Hoberlein	126.98	(127.49)
Zirconium, Venable	90.78	(90.40)
Thorium, Brauner	232.41	(232.63)
Praseodymium, Jones	140.46	
" Von Schele	140.40	(143.6)
" Brauner	140.95	
Neodymium, Jones	143.6	
" Boudouard	143.045	(140.8)
" Brauner	143.5	

The methods used by Armitage in the case of boron have been subjected to much unfavorable criticism. At the close of the article the author gives his revised table of atomic weights by the side of those of Richards and the German Committee. It is much to be regretted that both the author and the German Committee have ignored the usual practice in regard to significant figures, curiously enough in opposite directions, the latter retaining such a number of figures that the last one is certain, while the author retains always two decimals without reference to the probable accuracy of the result.

The Nature of Valence. By F. P. Venable. *J. Am. Chem. Soc.*, **21**, 192–200; 220–231.—Besides presenting at length the views of other chemists the author proposes the hypothesis that valence is not an inherent property of the single atom, but is the resultant of the mutual influence of the atoms entering into combination, "the number of atoms forming one molecule being purely a matter of equilibrium and dependent on the motion of those atoms." The author does not show, however, that this indefinite hypothesis leads to any specific or tangible results. In regard to it the reviewer would remark, somewhat in line with Lothar Meyer's statement quoted by the author, that it is only in so far as valence can be regarded as a constant property of the atom, or in so far as the conditions of its variation can be specifically stated, that the concept of valence has any scientific value.

The Rise of the Theory of Electrolytic Dissociation, and a Few of Its Applications in Chemistry, Physics, and Biology. By Harry C. Jones. *Johns Hopkins Hospital Bull.*, **87**, 1–10.—A brief address on the subject read before the medical society.

Natural Science of the Ancients as Interpreted by Lucretius. By F. P. Venable. *J. Elisha Mitchell Sci. Soc.*, **15**, 62–75.

The Solubility of Iodide in Dilute Potassium Iodide Solutions. By A. A. Noyes and L. J. Seidensticker. *J. Am. Chem. Soc.*, **21**, 217–220.—The authors show that the excess of iodine dissolved by potassium iodide solutions over that dissolved by pure water is proportional to the concentration of the iodide (between the concentrations 0.1 and 0.006 normal), and that this result is in accord with the assumption that the complex salt in solution has the formula KI_3, or more correctly that its anions which alone are present in important amounts have the corresponding formula I_3.

The Velocity of the Reaction between Silver Acetate and Sodium Formate. A Reaction of the Third Order. By Arthur A. Noyes and George T. Cottle. *J. Am. Chem. Soc.*, **21**, 250–256.—The velocity of the reaction, measured at 100°, is shown to be proportional to the concentration of the formate and the square of that of the silver salt corresponding to the fact that one molecule of the former substance reacts with two of the latter.

H. M. Goodwin, Reviewer.

Absorption of Gases in High Vacuum. By C. C. Hutchins. *Am. J. Sci.*, **157**, 61–63.—It was found that of the several gases investigated, namely cyanogen, nitrogen, iodine, and oxygen, the latter is by far the least rapidly absorbed by the discharge in a vacuum tube, and in consequence the vacuum in a tube containing this gas is less rapidly raised than in tubes filled with the other gases. The author suggests therefore introducing mercuric oxide around an auxiliary anode as an efficient and simple device for maintaining X-ray tubes at the exhaustion of maximum efficiency.

Note on the Transference Number of Hydrogen. By Wilder D. Bancroft. *J. Phys. Chem.*, **2**, 496–497.—This note refers to Hopfgartner's paper in connection with the work of McIntosh on the transference number of hydrogen (see *this Rev.*, **5**, 101). The discrepancies between the determinations by these investigators and those of Bein and Kohlrausch cannot yet be satisfactorily explained.

On the Heat of Solution of Liquid Hydriodic Acid. By F. C. Cottrell. *J. Phys. Chem.*, **2**, 492–495.—The liquid acid contained in a sealed glass tube was broken in a calorimeter of 500 cc. capacity and the rise of temperature noted. The mean of three determinations gave 148.3 K (1K = 100 g. cal. at 12°). Corrected for that portion of the acid present as saturated vapor in the sealed tube the value is 147.8. From this the molecular heat of condensation of the gas is computed to be 42.8 K.

Variance of the Voltaic Cell. By Wilder D. Bancroft. *J. Phys. Chem.*, 2, 227–240.—The author takes exception to Nernst's method of application of the phase rule to the Voltaic cell, and then illustrates its use in the case of numerous cells; the application of Le Chateliers theorem in predicting qualitatively the changes in the electromotive force produced by changes in the variables on which the electromotive force depends, is also illustrated by examples.

Electromotive Force between Amalgams. By Hamilton P. Cady. *J. Phys. Chem.*, 2, 551–564.—In this interesting paper the author has verified experimentally the independence, required by the osmotic theory, of the electromotive force of various amalgam cells, of the nature of the solvent, and of the concentration of the solution required. The anomalous results obtained for the molecular weights of the alkali and alkali-earth metals as computed from the electromotive force of such amalgam cells are shown to be in harmony with Ramsay's observations on the vapor-pressure of the same amalgams. These anomalies are shown to disappear when the heat of dilution of the amalgam, which was found to be not inconsiderable, is taken into account. The heat of dilution of sodium amalgam was found to be independent of the temperature between 4° and 22°. An error relative to the electromotive force due to polyatomic zinc ions is corrected by Mr. Bancroft, *J. Phys. Chem.*, 3, 107.

The Isothermal Pressure-surface in the Case of Two Single and One Double Salt. By F. Donnan. *J. Phys. Chem.*, 2, 417–420.—A graphical discussion of the phenomena attending evaporation of a system consisting of two dissolved salts possessing one ion in common.

Solution Densities. By H. T. Barnes and A. P. Scott. *J. Phys. Chem.*, 2, 536–550.—The authors have determined the densities of a number of salt solutions at various concentrations, and have constructed plots with differences between the observed densities and the values computed on the assumption that no volume change occurs on dissolving the salt as ordinates, and weights of dissolved substance as abscissae. From the plots thus obtained the authors believe that abrupt changes of curvature are unmistakable, although they do not seem to wish to advance or advocate any "hydrate" theory in explanation. That such breaks are really present, however, does not appear probable to the reviewer, nor are they evident in the data presented.

Dissociative Power of Solvents. By Louis Kahlenberg and Azariah T. Lincoln. *J. Phys. Chem.*, 3, 12–36.—To test Nernst's rule of the relation between dissociating power and

dielectric constant, the authors have studied qualitatively the relative dissociating power of some seventy-five organic liquids by means of the conductivity of salts dissolved in them. The chlorides of iron, antimony, bismuth and mercury were used as solutes. The rule was found to be verified with but few exceptions. In general the experiments show that solutions in hydrocarbons or their halogen substitution-products do not conduct; that alcoholic solutions conduct comparatively well, the power diminishing with increasing percentage of carbon in the molecule; that phenols conduct less than alcohols, ethers and acid anhydrides, slightly or not at all; aldehydes, relatively well; that nitriles and nitrogen compounds containing oxygen combined with the nitrogen both give conducting solutions, while amido compounds of the aromatic series do not. Numerous instances were noted which do not confirm Brühl's theory that solvents possessing dissociating power are unsaturated compounds, so that this theory is believed to be untenable. The paper also contains quantitative measurements of the conductivity of the chlorides mentioned above in some of the better conducting solvents, and both conductivity and freezing-point measurements on nitrobenzene solutions. The results in general indicate that cryoscopic and conductivity measurements do not in many cases agree in the case of non-aqueous solutions, and that an extension or modification of the dissociation theory may be necessary, when sufficient data to warrant general conclusions have been obtained.

Boiling-Point Curves. By E. F. Thayer. *J. Phys. Chem.*, 3, 36–40.—An extension of previous work (*this Rev.*, 4, 90) to mixtures of alcohol and chloroform, alcohol and acetone, and chloroform and acetone, is described. The chloroform-alcohol curve possessed a minimum boiling-point at 58.5° under 732.5 mm. pressure, for a mixture containing about 7 per cent. alcohol. The chloroform-acetone curve showed a maximum boiling-point at 63.4° under 737.1 mm. pressure, for a mixture containing about 19 per cent. acetone. All mixtures of alcohol and acetone boiled between the boiling-points of their two constituents.

Determination of the Molecular Rise in Boiling-point of Liquid Ammonia. By E. C. Franklin and C. A. Krauss. *Am. Chem. J.*, 20, 836–853.—A modified form of Beckmann apparatus suitable to this low-boiling solvent was used. The molecular elevation for water and for alcohol were satisfactorily constant, both giving the same value, 3.4. Other organic solutes gave less satisfactory values, but all were of about the same order of magnitude. The salts investigated, namely, ammonium nitrate, sodium nitrate, and potassium iodide gave, in view of

the high electrical conductivity of their solutions, values surprisingly low, indicating small dissociation. Metallic sodium gave a molecular elevation varying from 1.50 to 2.30, indicating a molecule containing two atoms in solution.

Some Properties of Liquid Ammonia. By E. C. Franklin and C. A. Krauss. *Am. Chem. J.*, **21**, 8–14.—The authors have compared, as far as existing data permit, the various physical properties of liquid ammonia with the corresponding properties of water, thus bringing out the close relationship between these two solvents. The properties discussed are the conductivity of ammonia solutions, ammonia of crystallization, specific and latent heats, boiling-point, molecular elevation of boiling-point, dielectric constant, and molecular association.

Note on the Spectra of Hydrogen. By Theodore W. Richards. *Am. Chem. J.*, **21**, 172–174.—The author points out in explanation of certain recent results of Hutton that water vapor gives the pure red spectrum of hydrogen more readily than hydrogen itself and that this spectrum is doubtless due to dissociated atoms rather than hydrogen molecules. The "white spectrum" of hydrogen, on the other hand, is obtained only in the absence of vapor; it is not to be regarded as due to impurities.

Specific Gravity of Sodium Chloride Solutions. By H. C. Hahn. *J. Am. Chem. Soc.*, **20**, 621–630.—Specific gravity determinations of solutions varying in concentration from 5 per cent. to saturation at 15° C. are given to six significant figures, and several interpolation formulae with three and four constants are calculated for expressing the results.

GENERAL AND PHYSICAL CHEMISTRY.

H. M. Goodwin, Reviewer.

A New Determination of the Electrochemical Equivalent of Silver. By Geo. W. Patterson, Jr., and Karl E. Guthe. *Phys. Rev.*, **7**, 258–282.—The discrepancy between the values of the mechanical equivalent of heat as determined by the direct and by the electrical method, led the authors to believe it might be due to errors in the standards used, in particular in the value of the ampere. A redetermination of the electrochemical equivalent was therefore undertaken. The investigation was carried out with great care in all its details, and is of particular value, as it does not involve either the acceleration due to gravity or the horizontal intensity of the earth's magnetism. The method consists essentially in balancing the electrodynamic action of the coils of a

primary electrodynamometer (of special design) against the torsional moment of a phosphor-bronze wire. The measurements involved are only those of mass and time, and the authors regard their results as accurate to one part in five thousand. A silver voltameter was used with the usual precautions. The final value—the mean of four determinations—of the electrochemical equivalent of silver was found to be 0.0011192+ gram per ampere per second. This value is about $\frac{1}{9}$ per cent. greater than that generally accepted. It agrees with the average value of Pellat and Potier, and is almost identical with that given by Kahle (0.0011193 gram). Assuming the above value, the discrepancy between Griffith's and Rowland's value for the mechanical equivalent of heat disappears.

On the Density of Ice. By Edward L. Nichols. *Phys. Rev.*, **8**, 21–37.—The first part of the paper contains a critical review of previous determinations of this constant, and brings out the fact that although the results of individual observers check well among themselves the agreement is not satisfactory when the results of different observers are compared. It seemed not unlikely that the nature of the ice itself was the cause of the discrepancy. To settle this point and particularly to determine the density of ice as formed in the ice calorimeter, the author made a number of careful determinations of ice from various sources, and found that the density is not the same under all circumstances, as is shown by the following values (referred to water at 0°): Ice frozen with carbon dioxide and ether, 0.91615 ± 0.00009; natural icicles, 0.91807 ± 0.00004; newly cut pond ice, 0.91804; pond ice one year old, 0.91644.

On the Dielectric Constant and Electrical Conductivity of Liquid Ammonia. By H. M. Goodwin and M. de Kay Thompson, Jr. *Phys. Rev.*, **8**, 38–48.—The di-electric constant of liquid ammonia was measured by Drude's method of electrical resonance; and values varying from 21 to 23, according to the preparation of the ammonia, were obtained at its boiling-point (—34° C.) under atmospheric pressure. This value, which is very low compared with that of water, would seem to indicate that liquid ammonia is an exception to Nernst's Law, since reasoning from the experiments on the electrical conductivity of liquid ammonia solutions made by Cady and the authors, ammonia is probably a solvent of high dissociating power. A convenient method for measuring the conductivity of this solvent is described and results on solutions of silver nitrate are given.

On the Osmotic Pressure of Certain Ether Solutions and Its Relation to Boyle-van't Hoff's Law. By H. M. Goodwin and Geo. K. Burgess. *Phys. Rev.*, 7, 171–187.—The lowering of

the vapor-pressure of solutions of naphthalene, benzophenone, and diphenylamine in ether was measured directly, by causing the solutions and the pure solvent to boil at constant temperature. Equality of temperatures was indicated by a platinum resistance thermometer placed in the boiling flasks, and pressures were measured on a mercury manometer by means of a cathetometer. From the observed vapor-pressure lowerings the corresponding osmotic pressures, P, of the solutions were computed by an exact formula which took into account the deviations of the pressure of the solvent vapor from Boyle's Law. The concentration of the solutions was reduced to mols per liter by means of specific gravity determinations, so that a direct investigation of the relation $PV = RT$ could be made. It was found that the product PV instead of being constant, diminished in all cases with increasing concentration. The form of the PV curves varied with the solute, and was in general similar to the well-known curves exhibited by imperfect gases under high pressure. It would seem that each solute therefore deviates from the Boyle-van't Hoff Law in much the same way that most gases deviate from the ideal gas laws, each substance having its own characteristic "condition-equation." Azobenzene investigated by Noyes and Abbot follows the perfect gas laws more nearly than any of the other substances thus far investigated.

ANALYTICAL CHEMISTRY.

ULTIMATE ANALYSIS.

H. P. TALBOT, REVIEWER.

The Determination of Potash as Perchlorate. BY F. S. SHIVER. *J. Am. Chem. Soc.*, **21**, 33–42.—Following a review of the various methods proposed for the determination of potassium, the author presents the results of experiments from which he concludes that the method of Caspari (*Ztschr. angew. Chem.*, *1893*, 68), as modified by Kreider (*Am. J. Sci.*, **149**, 443), will yield results equal in accuracy to those obtained by the use of platinum, in the case of mixtures free from other bases and non-volatile acids, and that it seems likely to prove satisfactory in the presence of these substances. Four procedures for the preparation of perchloric acid, those of Schlösing and of Porrey (both to be found in Grandeau's *Traité d'Analyse des Matieres agricoles*, **1**, 88–91), Caspari (*Ztschr. angew. Chem.*, *1893*, 68), and Kreider (*Loc. cit.*), are briefly described.

A New Method for the Determination of Zinc. BY A. C. LANGMUIR. *J. Am. Chem. Soc.*, **21**, 115–118.—In the method proposed, the zinc precipitate (sulphide) is dissolved in nitric

acid, the solution evaporated, and the zinc converted to oxide by ignition. It is recommended that the zinc be thrown down from a dilute solution, and that the precipitate be dissolved without washing, to avoid the usual difficulties at this point, and that the impurities in the ignited oxide be determined and deducted from the apparent weight. In the analysis of many alloys containing zinc, the solution from which the copper and lead have been removed by electrolysis, may be directly evaporated and the residue strongly ignited.

The Determination of Arsenic in Glycerine. By A. C. LANGMUIR. *J. Am. Chem. Soc.*, **21**, 133–136.—The glycerine is destroyed by evaporation with sulphuric and nitric acids, transferred to a Marsh generator, and the gas passed through a hard glass tube, constricted as usual, with a piece of filter-paper moistened with mercuric chloride solution beyond the constriction to detect any escaping arseniuretted hydrogen. The portion of the tube containing the mirror is cut off and weighed. It is then cleaned, dried, and again weighed. The Gutzeit test, using mercuric chloride instead of silver nitrate, also yields good results.

Note—Drown's Method of Determining Silicon. By A. C. LANGMUIR. *J. Am. Chem. Soc.*, **21**, 215.

Notes on the Rapid Determination of Tungsten in Steel. By GEORGE AUCHY. *J. Am. Chem. Soc.*, **21**, 239–245.—The author finds that the amount of ferric oxide which remains with the tungstic acid in the Blair procedure is, for the same class of steels, fairly constant, and that fusion with sodium carbonate may possibly be omitted. He finds that the amount of hydrochloric acid present when the tungstic acid is filtered off affects the determination, and that evaporation to dryness from a nitric acid solution does not always effect complete separation of the tungsten, while the separation is complete when hydrochloric acid is used. About 5 cc. of hydrochloric acid should be present when filtration takes place. In low phosphorus steels, the phosphorus may be determined as usual in the presence of the tungsten, provided the precipitate does not stand more than 2½ hours, and an excess of ammonia is avoided. The same procedure as for steels is found to succeed with ferrotungstens.

W. H. WALKER, REVIEWER.

Volumetric Method for the Estimation of Boric Acid. By L. C. JONES. *Am. J. Sci.*, **157**, 147–153.—In order that boric acid may be estimated volumetrically by titration with standard alkali, it is necessary to obtain it as the uncombined acid in a solution of neutral salts free from carbonic acid. The following

procedure is found to fulfil these requirements more perfectly than any other method hitherto proposed, and to furnish a rapid and convenient method for estimating boric acid in any compound decomposable by hydrochloric acid. The boric acid is set free by the addition of dilute hydrochloric acid in slight excess, and 5 cc. of a ten per cent. barium chloride solution are added to combine with any carbonic acid that may subsequently be introduced with the standard alkali solution. The excess of hydrochloric acid is now destroyed by adding a considerable quantity of a solution of potassium iodate, and the iodine set free by this reaction is taken up by a dilute solution of sodium thiosulphate. The boric acid may now be neutralized by standard sodium hydroxide, phenolphthalein being used as an indicator. When the red color first appears, 1–2 grams mannite are added and the alkali again run in to a faint alkaline reaction, which if permanent on the addition of more mannite, may be taken as the end-point. The best results are obtained in a cold concentrated solution, and under these conditions the experimental data given show the method to be very accurate.

PROXIMATE ANALYSIS.

A. H. GILL, REVIEWER.

The Heat of Bromination Test for Oils. BY AUGUSTUS H. GILL AND ISRAEL HATCH, JR. *J. Am. Chem. Soc.*, **21**, 27–29. —The calorimeter employed was double jacketted. The values obtained with the oils were compared with that obtained by brominating camphor; the results are expressed as a "specific temperature reaction," which, by multiplying by a constant, gives an iodine number which agrees well with that found in the usual way.

The Analytical Constants of American Linseed Oils. BY AUGUSTUS H. GILL AND AUGUSTUS C. LAMB. *J. Am. Chem. Soc.*, **21**, 29–30.—The specific gravity, Valenta, Maumené, iodine, and drying tests of raw, boiled, and bleached oils of undoubted purity are given.

Analytical Research on Sod Oil. BY E. HOPKINS, D. L. COBURN, AND E. SPILLER. *J. Am. Chem. Soc.*, **21**, 291–300.—Sod oil is the excess of oil extracted from ordinary leather in the currying process, menhaden and cod oils being used principally for this purpose, although other oils and greases are employed. It can hence have no well-defined constants, but there is little difficulty in distinguishing it from other oils. Moisture is determined by sucking air through the oil absorbed upon filter papers contained in a tube heated in an oven at 100° C. The oil is obtained by extracting this residue with 40° b. pt. gaso-

line ; and this is followed by extraction with alcohol giving the soap ; upon igniting the residue the ash is determined, and the hide fragments are ascertained by difference. Dégras former is estimated by saponifying the oil, evaporating to dryness, extracting the soap formed with water, and precipitating this with salt. The solution is filtered, the dégras former passing into the filtrate, where it is precipitated by hydrochloric acid ; it is filtered off and dissolved in alcohol, the alcohol is evaporated, and the residue weighed. In addition to these determinations, tables are given showing the saponification number, mineral acid, free acid, total acid, ether number, Reichert-Meissl, iodine, and unsaponifiable numbers.

The Absorption of Methane and Ethane by Fuming Sulphuric Acid. By R. A. Worstall. *J. Am. Chem. Soc.*, **21**, 245–251.—The article shows that contrary to accepted facts, both these gases are absorbed by the acid. The absorption in the case of methane was as follows : In ½ hour, 0.1 cc. ; in 2 hours, 1.7 cc. ; in 4 hours, 5.4 cc. ; 24 hours, 6.8 cc. ; and in 5 days, 11 cc. Natural gas containing 96 per cent. of methane showed an absorption varying from 0.3 to 3.3 per cent. Ethane is absorbed in a quantity varying from 3.5 to 7 per cent. The results of this investigation show that in gas analysis the gas should not stand longer than an hour over sulphuric acid, and if ethane be present not more than fifteen minutes.

A. G. Woodman, Reviewer.

Butter and Butter Adulterants. By C. B. Cochran. *J. Franklin Inst.*, **157**, 85–97.—For the purpose of detecting and estimating small amounts of foreign fat in butter, the author considers the following tests most satisfactory : Direct microscopic examination of the sample by polarized light ; microscopic examination of the crystals from solution in amyl alcohol, both with and without polarized light ; Valenta test ; Reichert number ; reading of butyrorefractometer. It is concluded that if the conditions of crystallization are kept uniform the crystalline deposit obtained from the solution of pure butter-fat in amyl alcohol is characteristic of butter. Photomicrographs are given illustrating this. Results are also given of the examination of several samples of renovated butter ; that is, stale butter in which the fat has been separated from the curd and water, and then emulsified with milk or buttermilk, being thus made again into butter.

Detection of Caramel in Spirits and Vinegar. By C. A. Crampton and F. D. Simons. *J. Am. Chem. Soc.*, **21**, 355–358.—It has been found that fuller's earth has a greater affinity for the artificial coloring-matter of spirits than for that derived

naturally from the wooden containers, and the method given for the detection of caramel is based upon the observation that a much greater percentage of color is removed from the artificially colored samples by means of this substance.

G. W. ROLFE, REVIEWER.

Study of Starch Grains and Its Application. BY H. KRAEMER. *Am. J. Pharm.*, 71, 174–189.—This paper treats of the origin of starch in plants as indicated by the researches of the biologist and botanist, and of the physical and chemical examination of starch by the microscope. The author argues for more expert work by the botanist and biologist in food analysis.

Some Notes on the Estimation of Carbohydrates. BY F. W. TRAPHAGEN AND W. M. COBLEIGH. *J. Am. Chem. Soc.*, 21, 369–373.—The authors describe their modification of the Fehling determination. They measure the amount of precipitated copper oxide volumetrically by the permanganate method. They eliminate errors to a large extent by checking the process on solutions of similar known composition and of practically identical reducing value. Excellent results are obtained. As the Fehling determination is influenced so much by apparently insignificant points of manipulation, a more detailed description of the authors' method would be desirable.

E. H. RICHARDS, REVIEWER.

The Estimation of Nitrates and Ammonia in Water. BY FRANK X. MOERK. *Am. J. Pharm.*, 71, 157–161.—Instead of using milk of alumina to remove the organic matter which interferes with the color in the phenol-sulphonic acid test for nitrates in water samples, the author makes a duplicate determination for color due to the organic matter. The remarks on ammonia determinations do not agree with the experience of the reviewer; for, while it is true that "dilute ammonium chloride will not keep indefinitely," unless under conditions of complete sterilization, it is not true "that it is useless to attempt" to free alkaline potassium permanganate "from ammonia, as it cannot be kept so." With pure reagents and suitable preparation of them, the solution, even if not at first, yet on standing, yields ammonia-free distillates.

BIOLOGICAL CHEMISTRY.

A. G. WOODMAN, REVIEWER.

Digestive Ferments with Especial Reference to the Effects of Food Preservatives. BY HENRY LEFFMANN. *J. Franklin Inst.*, 147, 97–108.—The author has studied the action of the

more commonly used food preservatives in preventing starch digestion by various enzymes. A number of qualitative experiments in which the action was followed by means of tests with a solution of iodine in potassium iodide are recorded, and in a few cases the amount of dextrose formed was determined by Fehling's solution. It was found that salicylic acid is distinctly antagonistic to the starch-converting enzymes but does not interfere very much with proteid digestion; sodium benzoate, boric acid, borax, and boroglycide do not interfere appreciably with either starch or proteid digestion; beta-naphthol interferes with the action of malt-diastase but not seriously with taka-diastase or pancreatic extract, although it interferes decidedly with the peptic and pancreatic digestion of proteids. Sodium fluoride and sodium silicofluoride offer but little hindrance to starch transformation except in the case of the pancreatic digestion.

On the Presence of Cholin and Neurin in the Intestinal Canal during Its Complete Obstruction—A Research on Autointoxication. By BEATTIE NESBITT. *J. Expt. Medicine*, 4, 1–18.—The author has carried out experiments on dogs by closing the intestinal canal by means of a ligature, the animals having been fed on yolks of eggs, which are very rich in lecithin. The contents of the intestine were examined, care being taken to avoid the decomposition of the lecithin during analytical treatment, and cholin and neurin were detected and separated by means of their platinum salts. The conclusion is reached that complete occlusion of the small intestine at its lower end causes the formation of cholin and neurin, possibly other bases also, if the food given contains any considerable amount of lecithin.

Action of Formaldehyde on Enzymes and on Certain Proteids. BY C. L. BLISS AND F. G. NOVY. *J. Expt. Medicine*, 4, 47–80.—A systematic study has been made of the action of formaldehyde on various preparations of pepsin, rennin, pancreatin, ptyalin, diastase, and papaïn. The method adopted was to dissolve a certain amount of the ferment in distilled water and divide this solution into portions. A definite amount of "formalin" was added to each portion so that the liquid contained known amounts of formaldehyde, varying usually from 1 : 100 to 1 : 1000. These mixtures were allowed to stand in closed flasks at ordinary room temperature, portions being tested from time to time. Fresh, well-washed blood fibrin was used to test the proteolytic ferments, and freshly prepared starch paste for the diastatic experiments. It was found that fibrin is altered and rendered less digestible by formaldehyde; similarly, the casein of milk undergoes rapid alteration in contact with form-

aldehyde, and is only very slowly coagulated by rennet and is digested with difficulty by the proteolytic ferments. Pepsin was not affected even by a five per cent. solution of formaldehyde acting for three weeks, and the same general result was reached in the case of rennet. Papaïn was very quickly altered by formaldehyde even in very dilute solution, and trypin was also altered greatly, depending, however, on the amount of organic matter that was present. Ptyalin, like the diastatic ferment of the pancreas, was found not to be destroyed by dilute solutions of formaldehyde, but was destroyed after some time by strong solutions. Malt diastase was not destroyed by formaldehyde in moderate amounts and at room temperature. The favoring action of formaldehyde on diastase is considered to be really due to the protection of the diastase against decomposition by preventing the growth of the micro-organisms.

Analysis of Commercial Vinegar. By Frank G. Ryan. *Am. J. Pharm.*, 71, 71–73.—The author presents the results of analysis of three commercial samples of vinegar obtained by the methods recommended by Smith (*this Rev.*, 4, 63).

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[CONTRIBUTION FROM THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.]

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ARTHUR A. NOYES, Editor.
REVIEWERS: Analytical Chemistry, H. P. Talbot and W. H. Walker; Biological Chemistry, A. G. Woodman; Carbohydrates, G. W. Rolfe; General Chemistry, A. A. Noyes; Geological and Mineralogical Chemistry, W. O. Crosby and M. L. Fuller; Inorganic Chemistry, Henry Fay; Metallurgical Chemistry and Assaying, H. O. Hofman; Organic Chemistry, J. F. Norris; Physical Chemistry, H. M. Goodwin; Sanitary Chemistry, E. H. Richards; Technical Chemistry, A. H. Gill and F. H. Thorp.

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INORGANIC CHEMISTRY.

Henry Fay, Reviewer.

On an Isomer of Potassium Ferricyanide. By James Locke and Gaston H. Edwards. *Am. Chem. J.*, **21**, 193–206.—By treating potassium ferricyanide with potassium chlorate and hydrochloric acid Skraup obtained a red solution from which, by repeated precipitations with alcohol, he obtained an amorphous, hygroscopic powder, to which he assigned the formula $K_3Fe(CN)_6$, although he was not able to prepare it in pure condition. The authors, by modifying Skraup's conditions, have been able to obtain a pure crystallized product. Potassium ferricyanide was heated to 95° C. with hydrochloric acid and potassium chlorate until effervescence began. The solution was cooled to 20° and filtered; and to the cool filtrate slightly less than an equal volume of alcohol was added. This produced a heavy crystalline precipitate. By partial reprecipitation the crystals were obtained pure, and on analysis were shown to have the composition represented by the formula $K_3Fe(CN)_6.H_2O$. The substance is an isomer of potassium ferricyanide, and the authors propose to name it potassium β-ferricyanide. Like the ordinary salt, this isomer yields characteristic precipitates with the solutions of the heavy metals. These have, in general, the same characteristics as the salts of the normal ferricyanide, and in some cases pass over into the latter with extreme ease. The precipitate of the β-ferricyanide with silver nitrate is dark-brown and flocculent, and when heated in its mother-liquor to 100° passes over into the bright-orange of the α-ferricyanide. The potassium β-ferricyanide can readily be distinguished from the normal ferricyanide by the fact that with bismuth nitrate solutions it does not form a precipitate, while the α-ferricyanide produces an insoluble straw-colored precipitate. Stannic chloride, on the other hand, yields no precipitate with potassium α-ferricyanide, but precipitates the isomer completely. No explanation of the isomerism is offered.

On the Formation of Potassium β-Ferricyanide through the Action of Acids upon the Normal Ferricyanide. By James Locke and Gaston H. Edwards. *Am. Chem. J.*, **21**, 413–418.—It has been shown that the conversion of potassium ferricyanide into potassium β-ferricyanide can be accomplished by any acid, the presence of potassium chlorate not being necessary, as was assumed in a previous paper. Potassium ferricyanide was treated with hydrochloric acid, and from time to time portions were drawn off and precipitated with bismuth nitrate. Subsequently, the percentages of cyanogen which these precipitates contained were determined by reduction with sodium amalgam and titration to potassium α-ferricyanide. The rate of conversion from β- to α-ferricyanide brought about by the catalytic action of acids seems to be directly proportional to the degree of ionization of the acid.

The Action of Metals on Nitric Acid. By Paul C. Freer and George O. Higley. *Am. Chem. J.*, **21**, 377–392.—In previous papers the action of copper, lead, and silver on nitric acid of different strengths has been described. In this research the action of iron on nitric acid, and the effect of electrolytic hydrogen on it, using kathodes of copper, silver, and lead, have been investigated. When iron is dissolved in nitric acid, the reduction-products are nitrogen dioxide, nitric oxide, nitrous oxide, and ammonia. With acid of specific gravity 1.40 nitrogen dioxide and nitric oxide are obtained in proportions varying with the amounts of solvent. These differences caused by using varying amounts of solvent led the authors to the view that nitric oxide is solely a secondary product of the decomposition of the dioxide by water. As the acid diminishes in strength the variation in the relative amounts of these two products is much like that observed with copper, silver, and lead, until a specific gravity of 1.30 is reached when nitrous oxide is formed. With acid having a specific gravity of 1.25 the reaction is further complicated by the appearance of nitrogen and ammonia, the former reaching a maximum at 1.15 and then falling off, while the latter rises to a maximum at 1.05. With platinum electrodes, electrolytic hydrogen acts upon concentrated nitric acid much the same as do copper, silver, and iron, nitrogen dioxide being the principal product. Nitric oxide is produced with acid of specific gravity 1.35, and hydrogen begins to be liberated when acid of 1.30 sp. gr. is used. Small amounts of ammonia are formed only with dilute acid. The activity of electrolytic hydrogen depends, in a marked degree, upon the character of the electrode upon whose surface it is liberated. When nitric acid having a specific gravity of 1.05 is subjected to electrolysis in cells having kathodes of silver and lead, respectively, on the

surface of which kathodes there is equal current density, the reduction-products are the same; *i. e.*, nitrogen and ammonia in approximately the same proportions. On the other hand, copper, when made the kathode of an electrolytic cell containing acid of the same strength, has a much greater energizing effect upon the hydrogen deposited upon its surface than is shown by lead under the same circumstances, and produces about three times as much ammonia as the latter. Since in the electrolysis of nitric acid the action of the metallic ions is excluded, and the reduction must be effected by the hydrogen in contact with the surface of the different metals, it follows that the widely different results obtained when lead and silver dissolve in nitric acid cannot be attributed to the hydrogen atoms alone, but must also involve the direct deoxidizing effect of the metals themselves. With concentrated, non-ionized acid the metals alone cause the change, but on dilution both metals and hydrogen cause it.

Preparation of Metallic Tellurium. By Victor Lenher. *J. Am. Chem. Soc.*, **21**, 347–351.—The author has tried the different methods for the extraction of metallic tellurium from the slimes of the Baltimore Copper Works, and concludes that "reducing sugars will give a very practical method for the preparation of metallic tellurium."

Action of Hypophosphorous Acid upon Molybdic Acid. By Clarence Ebaugh and Edgar F. Smith. *J. Am. Chem. Soc.*, **21**, 384–386.—A tenth-normal solution of molybdenum trioxide was reduced by hypophosphorous acid both in the presence of a definite excess of that acid and in the presence of sulphuric acid. The reduction is approximately to the oxide Mo_2O_5. Neutral solutions are not reduced.

New Method for the Preparation of Cesium. By Hugo Erdmann and A. E. Menke. *J. Am. Chem. Soc.*, **21**, 259–262.—Almost the theoretical yield of cesium was obtained by heating cesium hydroxide with magnesium powder in a red-hot tube, through which a current of hydrogen was passing.

The Specific Gravity of Cesium. By A. E. Menke. *J. Am. Chem. Soc.*, **21**, 420–421.—Not less than four grams of metal were weighed first in hydrogen, then under liquid paraffin. The mean of six determinations gives the value 2.400 for the specific gravity.

The Solubility in Water of Certain Natural Silicates. By George Steiger. *J. Am. Chem. Soc.*, **21**, 437–439.—Certain silicates were found to give up alkali on long standing with water. The amount of alkali which went into solution was determined by means of standardized hydrochloric acid, using methyl orange as indicator.

ORGANIC CHEMISTRY.

J. F. NORRIS, REVIEWER.

Contribution to Our Knowledge of the Oil of Lemon Grass. BY WILH. STIEHL. *Am. Chem. J.*, **21**, 67–94.—The author shows by a review of the literature that the knowledge of the aldehydes present in the oil of lemon grass is very indefinite. Dodge (*Am. Chem. J.*, **12**, 555) isolated a characteristic aldehyde, $C_{10}H_{16}O$, from the oil and called it citriodoric aldehyde. Later, Tiemann and Semmler (*Ber. d. chem. Ges.*, **26**, 2708) separated geranial, and Doebner (*Ber. d. chem. Ges.*, **27**, 2020) citronellal. Barbier and Bouveault (*Compt. rend.*, **118**, 953, 1050) then showed that citronellal was not present in the oil, and from a study of the semi-carbazones proved that the three aldehydes present were geranial, citriodoric aldehyde, and laevo-licarhodal. And finally, Tiemann (*Ber. d. chem. Ges.*, **31**, 820) asserted that the only aldehyde present in the oil of lemon grass is geranial. The author found it impossible to separate the constituents of the oil by fractional distillation, but by the action of a solution of sodium bisulphite, succeeded in obtaining three aldehydes in pure condition. By using the proper conditions, the bisulphite compound of citriodoric aldehyde remains in solution, that of geranial separates in crystals, and the addition-product of the third compound, allo-lemonal, is decomposed, setting free the aldehyde as an oil. The semi-carbazones, the α-alkyl-β-naphthocinchoninic acids, and the condensation-products with acetone of the three aldehydes, were prepared, and their physical constants determined. It is shown that geranial is not present in natural oil of lemon grass, but that it is formed from the other two aldehydes, a freshly prepared, strongly acid solution of sodium bisulphite effecting the change readily. On the other hand, when geranial is boiled with an aqueous solution of sodium acetate, it is converted into citriodoric aldehyde and allo-lemonal. The condensation-products of the latter aldehydes with acetone readily condense into ring bodies isomeric with ionone, which was obtained by Tiemann in an analogous way from geranial. They have the characteristic odor of violets. From his own work and a study of the literature the author assigns the following formulas to the aldehydes:

$$(CH_3)_2{=}C{=}CH{-}CH_2{-}CH_2{-}C(CH_3){=}CH{-}CHO,$$

Citriodoric aldehyde.

$$(CH_3)_2{=}C{=}CH{-}CH_2{-}CH{=}C(CH_3){-}CH_2{-}CHO,$$

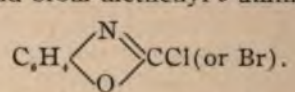
Geranial.

$$(CH_3)_2{=}C{=}CH{-}CH{=}CH{-}CH(CH_3){-}CH_2{-}CHO.$$

Allo-lemonal (*l*-licarhodal).

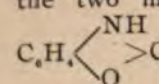
On the Constitution of the Salts of the Imido Ethers and Other Carbimide Derivatives. By Julius Stieglitz. *Am. Chem. J.*, **21**, 101–111.—This paper is an introduction to two articles by McCoy and by Dains, which are reviewed below. It states briefly the reason for accepting the view that the salts of the imido ethers are formed by the addition of the acid at the double bond, the acid radicle uniting with carbon, in preference to the older view that the salt formation is due to the change in volume of the nitrogen atom.

On the Hydrochlorides of Carbophenylimido Derivatives. By Herbert N. McCoy. *Am. Chem. J.*, **21**, 111–167.—Lengfeld and Stieglitz (*Am. Chem. J.*, **16**, 70; **17**, 98), in the course of a study of the action of phosphorus pentachloride on phenyl urethane, were led to examine the question whether the salts of imido ethers are formed by the addition of acid to the double bond between carbon and nitrogen or by direct addition to the nitrogen atom alone. If the former view is the correct one, the same compound should be formed by the action of hydrochloric acid on ethyl phenylimidobromformate and of hydrobromic acid on ethyl phenylimidochlorformate. These reactions were studied, and, although the reaction-product could not be isolated on account of its great instability, the decomposition-products were identical in both cases. In order to bring more evidence to bear on the subject, the author has investigated two analogous compounds, chlor- and brom-methenyl-*o*-aminophenol,



$$C_6H_4\left\langle\begin{matrix}N\\O\end{matrix}\right\rangle CCl(\text{or Br}).$$

These compounds, when treated with hydrobromic and hydrochloric acids, respectively, yielded the same product, which from the two methods of preparation must have the formula



$$C_6H_4\left\langle\begin{matrix}NH\\O\end{matrix}\right\rangle CClBr.$$

The nitrate and chlorplatinate of chlormethenylaminophenol were analyzed, thus establishing the salt-like nature of the compounds, although the halogen in them was joined to carbon. A number of methods of preparing the necessary aminophenols were studied. By the action of chlorine or bromine on the compound $O.C_6H_4.NH.CS$ the corresponding chlor- or brommethenylaminophenol was prepared with excellent yield. An attempt was made to convert carbonylaminophenol, $O.C_6H_4.NHCO$, by means of phosphorus pentachloride into chlormethenylaminophenol. A mixture of compounds, from

which a very small amount of the phenol could be isolated, was obtained, thus showing that the action of phosphorus pentachloride on urethane is very complicated. In order to prepare the carbonylaminophenol required for the above experiments a new method of preparation was tried, starting from salicylic amide, based on the molecular rearrangement which the bromamides show when treated with alkalies or alcoholic sodium methylate. As a result, 3,5-dibromcarbonylaminophenol was formed, from which the bromine was readily removed by reduction. In order to establish the structure of the monohydrochloride of carbodiphenylimide, $C\begin{cases} NC_6H_5 \\ NC_6H_5 \end{cases}$, a study was made of its action on benzene in the presence of aluminium chloride. Since in nearly all syntheses with the Friedel and Crafts reaction the halogen reacting is united with carbon, and since a well-defined condensation-product was obtained in the above case, the conclusion is drawn that in the hydrochloride the chlorine is joined to carbon. By a complete synthesis, in which the structure of the compounds could be followed, the product of the above reaction was shown to be either 2,4-diphenylimido-3(N)-phenyltetrahydroquinazoline or 2-phenylamido-3(N)-phenyl-4-phenylimidodihydroquinazoline. The compound exists in two forms, which are readily converted into each other by recrystallization.

On the Isourea Ethers and Other Derivatives of Ureas. By F. B. Dains. *J. Am. Chem. Soc.*, **21**, 136–192.—The work reported deals chiefly with methods of preparation of isourea ethers and a study of their physical and chemical properties. The compounds are of special interest because they contain both the amidine and imido ether groups. The presence of these two groups so modifies the compounds that they do not show a number of the characteristic reactions of imido ethers. The conclusion is drawn that the chemical behavior of the isoureas depends in a marked degree on the nature of the radicles present. The great number of facts presented makes a brief review of the paper impossible.

On the Rearrangement of Imido Esters. By H. L. Wheeler and T. B. Johnson. *Am. Chem. J.*, **21**, 185–193.—When silver formamide suspended in ether was heated in an open vessel with ethyl iodide, ethyl phenylimidoformate, $HC\begin{cases} NC_6H_5 \\ OC_2H_5 \end{cases}$, was obtained. When, however, the silver salt of the amide and an excess of ethyl iodide were heated in a sealed tube at 100°, the entire reaction-product was N-ethylformanilide,

$$(C_2H_5)(C_6H_5)N.CH:O.$$

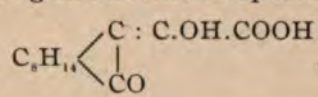
This tautomeric reaction of the silver salt is remarkable, since the difference in conditions in the two experiments is so small; and it shows clearly that synthesis cannot be relied upon as positive evidence in deciding structure. The best explanation of the facts is given by assuming the formation of an intermediate addition-product which can break down in two ways with the elimination of ethyl iodide. A rearrangement was shown also to take place with benzimidoethyl ester, which was converted into ethyl benzamide when heated with ethyl iodide at 100°.

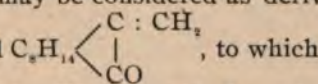
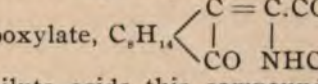
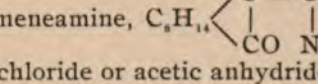
Reaction of Orthodiazobenzoic Acid with Sulphurous Acid and Copper Powder. By W. E. Henderson. *Am. Chem. J.*, **21**, 206–210.—In order to test the statement made in text-books and chemical dictionaries that sulphonic acids are formed by the action of sulphurous acid on diazo compounds in the presence of copper powder, the decomposition of *o*-diazobenzoic acid sulphate under these conditions was studied. A reaction took place readily in the cold without the formation of any tarry products, and a yield of 50 per cent. of the theoretical of dithiosalicylic acid was obtained. Copper went into solution as the reaction proceeded, forming a mixture of cuprous and cupric salts, and a part of the sulphurous acid was oxidized to sulphuric acid. The reducing power of the sulphurous acid probably prevented the formation of a sulphuric acid. As the thio acid yields *o*-sulphobenzoic acid on oxidation the reaction may be of value in the preparation of sulphonic acids.

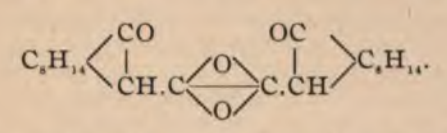
Direct Nitration of the Paraffins. By R. A. Worstall. *Am. Chem. J.*, **21**, 210–218.—The author has repeated his study of the nitration of the paraffins by the method already described (*this Rev.*, **4**, 87), and has extended the investigation to a number of higher paraffins. The yields of nitro and dinitro compounds from hexane were 6 and 4 per cent. respectively; from heptane, 16 and 24 per cent.; from octane, 17.5 and 25 per cent.; from nonane, 22 and 48 per cent. From decane about 35 per cent. of nitrodecane was obtained when the hydrocarbon was heated with dilute acid (sp. gr. 1.08), which was found to yield the best results. This nitro compound and the derivative of nonane were separated from the unchanged hydrocarbon by conversion into sodium derivatives and subsequent treatment of the latter with carbon dioxide. Hendecane and dodecane gave small yields of mononitro derivatives. After 75 per cent. of the original hydrocarbons had been converted into nitration and oxidation-products, the residual paraffins, when boiled with nitric acid, still gave as oxidation-products acetic, succinic, oxalic, and carbonic acids. This fact seems to show that these acids are not due to the oxidation of naphthenes or other foreign hydrocarbons, as has been claimed by other observers.

Higher Primary Nitroparaffins. By R. A. Worstall. *Am. Chem. J.*, **21**, 218–238.—The properties of the nitro compounds mentioned in the preceding review are described fully in this paper. They were converted into amines and sodium derivatives, and from the latter compounds bromnitro derivatives were prepared. The nitro compounds were shown to be primary by the action of hydrochloric acid, which converted them into the corresponding fatty acids.

The Action of Ethylic Oxalate on Camphor. IV. By J. Bishop Tingle and Alfred Tingle. *Am. Chem. J.*, **21**, 238–261.—By heating aniline with camphoroxalic acid,

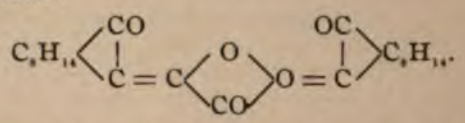


three compounds are formed, by varying the temperature of the reaction. These may be considered as derivatives of the hypothetical compound  , to which the name camphoformene is assigned. The following formulas for the compounds are deduced from their reactions: When the two substances are heated at 100° the resulting compound is aniline phenylcamphoformeneaminecarboxylate,  . By gentle heat or dilute acids this compound is converted into the corresponding acid, the aniline being split off from the carboxyl group. At 130° aniline and camphoroxalic acid give phenylcamphoformeneamine,  . By the action of benzoyl chloride or acetic anhydride on camphoroxalic acid, a substance is formed which is not changed by boiling sodium hydroxide, bromine in chloroform solution, or hydroxylamine. The compound is therefore probably not an anhydride, as was at first suggested, and the following formula is offered provisionally :



When camphoroxalic acid was boiled with acetic anhydride, a compound, in addition to the above and acetylcamphoroxalic

acid, was obtained. The formula which explains its reactions best is as follows:



When ethyl camphoroxalate is heated at 130° with aniline the product formed is phenylcamphoformeneaminecarboxylic anilide and not oxanilide, as stated in an earlier paper. By oxidizing ethyl camphoroxalate phenylhydrazide, ethyl camphoroxalate azobenzene, $C_8H_{14}\left\langle\begin{matrix}C : C.COOC_2H_5\\ \quad\quad |\\ CO \quad N : NC_6H_5\end{matrix}\right.$, was obtained. Attempts to condense camphor with diethyl pyrotartrate and with ethyl oxalacetate were made in hopes of getting two isomers in each case; but no well-defined products could be isolated. Further work on the physiological action of camphoroxalic acid shows that when injected intravenously to the extent of 0.241 gram per kilo of body weight, it is practically without effect.

On a Liquid Acetylene Diiodide. By Edward H. Keiser. *Am. Chem. J.*, **21**, 261–265.—When acetylene was passed over iodine heated to 140°–160° a slow absorption took place, and the resulting reaction-product consisted of a mixture of an oil and crystals. The crystals were the ordinary acetylene diiodide. The oil, after purification by repeated freezing and liquefaction, had a definite melting-point and boiling-point, and was shown to have the composition $C_2H_2I_2$ by an analysis and a molecular weight determination. Since the liquid acetylene diiodide changes into the solid variety by standing in contact with hydriodic acid, and since it is very stable in the air, whereas the compounds $CH_2{=}CCl_2$ and $CH_2{=}CBr_2$ readily absorb oxygen, it is concluded that it is a stereoisomer of the solid diiodide.

A Simple Color Reaction for Methyl Alcohol. By S. P. Mulliken and H. Scudder. *Am. Chem. J.*, **21**, 266–271.—By means of the following test the presence of one part of methyl alcohol in 10,000 parts of water or in 5 parts of ethyl alcohol can be readily shown. A hot copper spiral, which has been superficially oxidized, is dipped into the aqueous solution of the alcohol, one drop of a 0.5 per cent. solution of resorcin is added to the weak formic aldehyde solution thus formed, and the mixture is then poured slowly upon concentrated sulphuric acid. The presence of methyl alcohol is indicated by the appearance of a pure rose-red zone at the line separating the denser and lighter layers. In and above this colored band is suspended a white or

pinkish coagulum, which, after long standing, increases notably in color intensity, and finally separates and rises in purplish-red flocks. The test was applied to a large number of substances. The only other compounds studied which give colorations in the least resembling that caused by methyl alcohol, are secondary and tertiary butyl alcohols, dimethylethylcarbinol, and formic acid. With these compounds, however, no confusion need arise for the coloring-matter does not separate and rise to the surface in solid flakes.

Reactions for the Detection of the Nitro Group. By S. P. Mulliken and E. R. Barker. *Am. Chem. J.*, **21**, 271–276.—The first test described depends on the fact that all nitro compounds when dissolved in dilute alcohol are reduced, in the presence of calcium chloride, by zinc dust to hydroxylamines. The test is applied by dissolving three drops of the nitro body in 3 cc. of 50 per cent. alcohol, adding five drops of a 10 per cent. solution of calcium chloride, a small amount of zinc dust, and heating till violent boiling begins. The presence of a hydroxylamine derivative in the filtrate from the reaction mixture is shown by pouring a few drops of the clear liquid into a strongly ammoniacal solution of silver nitrate in dilute alcohol. The only important classes of nitrogenous compounds which do not reduce ammoniacal silver nitrate in the cold but which effect the reduction after treatment with zinc dust are nitroso, azo, and azoxy bodies. The second test depends on the fact that nitro compounds in the presence of iron and hydrochloric acid oxidize a mixture of equal parts of aniline, *o*-toluidine, and *p*-toluidine to rosaniline. Three drops of the nitro compound are boiled three minutes with 2 cc. of the above mixture, 2 cc. of distilled water, 2 cc. of concentrated hydrochloric acid, and 1 gram of iron filings. A few drops of the reaction-product are poured into dilute acetic acid in order to bring out the clear magenta color. The test is not very successful with trinitro derivatives, and is given by all compounds which contain oxygen linked to nitrogen. Iodoso- and iodobenzene give purplish-red solutions.

Aliphatic Sulphonic Acids. III.—(1) Bromethylenesulphonic Acid. By Elmer P. Kohler. *Am. Chem. J.*, **21**, 339–370.—When bromine reacts with ethylenesulphonic acid dissolved in water, fuming hydrobromic acid, or glacial acetic acid, the first result is the substitution of bromine for the α-hydrogen atom, which takes place at 0°. The (1)-bromethylenesulphonic acid so obtained is extremely unstable. When a moderately concentrated solution of the acid is heated to boiling and neutralized with a soluble carbonate, from 35 to 50 per cent. of it is decomposed—the bromine and sulphoxyl grouping being split off as bromide and sulphite. If an equally strong solution of the

potassium salt is boiled with the same carbonate, there is a rapid addition of water but no elimination of sulphite. Nascent hydrogen replaces the bromine in bromethylenesulphonic acid with hydrogen, potassium hydroxide with hydroxyl, and mercuric chloride with chlorine, but the acid does not lend itself to double decomposition, and it is impossible to link two molecules by eliminating the halogen by silver. (1)-Bromethylenesulphonic acid differs from the analogous carbonic acids in that, like ethylenesulphonic acid, it shows no tendency to combine with two atoms of the same kind or with two similar groups. Nascent hydrogen only replaces the bromine with hydrogen; and bromine, chlorine, and hypochlorous acid oxidize it in the cold. On the other hand, it combines with dissimilar atoms or groups far more readily than unsaturated carbonic acids. Water, hydrobromic acid, sulphuric acid, acetic acid, and acid sulphites are all slowly taken up in the cold. In all these cases the negative component of the molecule goes to the (2)-position. The (1,2)-oxyethanesulphonic acid obtained in this way is bromisethionic acid. A comparison of it with isethionic acid shows an important difference in the formation of anhydrides and in the behavior towards oxidizing agents. Where isethionates are heated they lose a molecule of water for two molecules of salt and pass into diisethionates. The salts of the brom-acid behave in the same way, but they are also capable of forming anhydrides from one molecule of salt. With potassium permanganate isethionates always give stable sulphoacetates. The same oxidizing agent completely destroys brom-isethionates, the products being carbon dioxide, water, hydrobromic acid, and sulphuric acid. Bromine, chlorine, and hypochlorous acid act in the same way on the ,brom acid, whereas nitric acid gives oxalic acid, silver oxide gives glycolic acid, and barium manganate which is kept neutral with a current of carbon dioxide gives bromsulphoacetic acid. (1,2)-Dihalogen ethanesulphonic acids were obtained by the action of phosphorus pentachloride on bromoxyethanesulphonic acid, and by the addition of hydrobromic acid to bromethylenesulphonic acid. The salts of these acids are quite stable. By prolonged boiling with water, alkaline carbonates, acetates, or silver oxide, the (2)-halogen can be completely replaced by hydroxyl, while the (1)-halogen and the sulphonic acid group are left intact. The alkalies and barium hydroxide instantly attack the (1)-halogen in the cold, splitting off halogen and the sulphonic acid group, and leaving aldehydes or their polymeric products. With zinc or magnesium both of the halogen atoms can be readily eliminated, leaving an unsaturated acid. Bromethylenesulphonic acid unites with one molecule of sulphuric acid at 80°, forming bromethylenedisulphonic acid. If the barium salt of the acid is heated with a large ex-

cess of sulphuric acid at 125° a salt of the following composition is obtained : $Ba\left\langle\begin{matrix}SO_2\\SO_2\end{matrix}\right\rangle CBr—CH\left\langle\begin{matrix}OH\\SO_2ba\end{matrix}\right. .2H_2O$. The acid is a bromine substitution-product of an acid which has already been obtained by the action of acid sulphites on chloral.

On the Hydrolysis of Acid Amides. By Ira Remsen. *Am. Chem. J.*, **21**, 281–284.—This paper is an introduction to one that follows by E. E. Reid (see next review), and points out the effect that a group has on another in the ortho position to it. The fact that *p*-sulphaminebenzoic acid is not acted upon when boiled with dilute hydrochloric acid, whereas benzoic sulphinide is first converted into the corresponding ortho acid and then into the acid ammonium salt of *o*-sulphobenzoic acid by the same reagent, led to a systematic study of the hydrolysis of acid amides.

Experiments on the Hydrolysis of Acid Amides. By E. Emmet Reid. *Am. Chem. J.*, **21**, 284–349.—The rate of hydrolysis of the amides studied was determined by drawing off samples of the solutions in which the hydrolysis was being effected by dilute acids or alkalies at definite intervals, and estimating the nitrogen present in the form of ammonia and that in the unchanged amide. Freshly precipitated magnesium hydroxide proved to be an excellent reagent to distinguish between the two forms of nitrogen. It readily set free ammonia from the ammonium salt, but did not affect the amide. After the ammonia had been distilled off sodium hydroxide was added and the nitrogen in the amide was determined. The experimental details were carefully worked out, and consequently very trustworthy results were obtained. Twenty-two amides were studied, which included the nitro, chlor, brom, iod, hydroxy, amido, methoxy, and ethoxy derivatives of benzoic acids. The results obtained with the meta- and para-substituted benzamides go to show that groups in these positions usually exercise some, though not a very marked, retarding influence on the rate of hydrolysis. The rate does not vary regularly with the change in molecular weight. The nitro group in the para position causes a very marked increase in the speed of hydrolysis. The experiments with the ortho-substituted benzamides all show that groups in this position exert a remarkable protective influence on the amide group, the reaction-constant for the ortho acids being roughly about one-tenth that of the meta acids. With similar groups this influence varies roughly with the weight of the group, but otherwise it seems to depend more upon the nature of the group than its weight. Methyl protects far better than chlorine or even than the methoxy group. The nitro group is remarkable in its

protective power, being twice as efficient as iodine. The methoxy and ethoxy groups have far less effect than hydroxyl.

Emetine Octoiodide and the Extraction and Estimation of Alkaloids Generally. By H. M. Gordin and A. B. Prescott. *J. Am. Chem. Soc.*, **21**, 231–239.—A detailed description of a new method of extraction of alkaloids from drugs, and directions for applying the authors' volumetric method for their estimation are given fully. By pouring an acidulated solution of emetine into an excess of iodine dissolved in potassium iodide, a periodide was precipitated which probably had the formula $C_{30}H_{40}N_2O_5.HI.I_7$.

Coumarin and Vanillin, Their Separation, Estimation, and Identification in Commercial Flavoring Extracts. By William H. Hess and Albert B. Prescott. *J. Am. Chem. Soc.*, **21**, 256-259.—Coumarin and vanillin are separated from an aqueous solution by extraction with ether which is then shaken with dilute ammonia. The coumarin remains dissolved in the ether while the vanillin goes into solution in the ammonia, from which it can be separated by means of dilute acid.

The Oxidation of Formic Aldehyde by Hydrogen Peroxide. By J. H. Kastle and A. S. Loevenhart. *J. Am. Chem. Soc.*, **21**, 262–276.—The effect of temperature, sunlight, acids, and bases on the reaction stated in the title was studied. The rate of the reaction increases very rapidly with rise in temperature. The accelerating effect of light is greatest at low temperatures, gradually diminishing with increasing temperature until at about 90° the effect disappears. The effect of acids is to increase the speed of the reaction but not to such an extent as has been observed in the case of other oxidation reactions which have been studied. Bases cause the oxidation to take place so rapidly that the reaction could be studied at ordinary temperatures only.

Upon the Action of Sulphuric Acid on Thymol, III. By James H. Stebbins. *J. Am. Chem. Soc.*, **21**, 276–281.—The principal product of the action of 66° sulphuric acid on thymol, at the temperature of the water-bath, was thymol-*p*-sulphonic acid. A very small amount of a second compound, which was probably a disulphonic acid, was also obtained.

Observations on Derivatives of Aconitic Acid. By D. C. Hanna and Edgar F. Smith. *J. Am. Chem. Soc.*, **21**, 381–383.—By distilling 90 grams of aconitic acid with phosphorus trisulphide about 0.7 gram thiophtene was obtained. Triethyl aconitic ester was produced by heating triethyl citric ester with phosphorus trichloride.

GEOLOGICAL AND MINERALOGICAL CHEMISTRY.

M. L. FULLER, REVIEWER.

Geology of Certain Counties of Iowa. BY A. G. LEONARD, SAMUEL CALVIN, AND H. FOSTER BAIN. *Iowa Geol. Survey, Ann. Rep.*, 8, 51–366.—The physiography, stratigraphy, and geological structure of each county is described, and a discussion is given of the economic products, accompanied by a number of analyses.

Properties and Tests of Iowa Building Stones. BY H. FOSTER BAIN. *Iowa Geol. Survey, Ann. Rep.*, 8, 367–416.

On the Phenocrysts of Intrusive Igneous Rocks. BY L. V. PIRSSON. *Am. J. Sci.*, 157, 271–280.—The objections to the hypothesis of an intratelluric origin of the phenocrysts are discussed, and evidence pointing to an origin by crystallization "in place" is presented. The supposed manner in which the development takes place is as follows: As the temperature of an intruded aqueous magma falls, centers of crystallization are set up, the intervals of crystallization of the component minerals becoming progressively shorter as the magma becomes viscous from the escape of the water-vapor. Thus, while the earlier, or ferro-magnesian, components may reach considerable size, the crystals of the later components are comparatively small. In the case of recurrent phenocrysts it is supposed that the most abundant components tend to set up centers of crystallization before their normal periods, the rest of the process continuing as before.

On the Occurrence, Origin, and Chemical Composition of Chromite. BY J. H. PRATT. *Am. J. Sci.*, 157, 281–286.—The usual mode of occurrence of the chromite of North Carolina is in the form of rounded masses of varying proportions in the peridotite near its contact with the inclosing gneiss. Its basic character is an indication of its insolubility in the peridotite magma; hence it would have been among the first of the minerals to solidify. Its relation to the inclosing rock confirms this view. With two exceptions, all analyses known show the presence of magnesium and aluminum, and the author concludes that chromite is really a combination of the three isomorphous molecules, $FeO.Cr_2O_3$, $MgO.Cr_2O_3$, and $MgO.Al_2O_3$. The $MgO.Al_2O_3$ is represented by the mineral spinel, and the discovery of $MgO.Cr_2O_3$ as a definite mineral may be expected.

Some Rock-forming Biotites and Amphiboles. BY H. W. TURNER. ANALYSES BY W. F. HILLEBRAND, H. N. STOKES,

AND WILLIAM VALENTINE. *Am. J. Sci.*, 157, 294–298.—The paper includes descriptions and very complete analyses of biotite from granite, quartz-monzonite, and gneiss from the Sierra Nevada region, and of the amphibole of gabbro and quartz-monzonite from the same locality. Complete analyses of most of the rocks are also given. The work was executed in the laboratory of the U. S. Geol. Survey, the object being to furnish a basis for calculating the molecular composition of the rocks in question.

On the Occurrence of Paleotrochis in Volcanic Rocks in Mexico. BY HENRY S. WILLIAMS. *Am. J. Sci.*, 157, 335–336. —More or less regularly striated biconical forms resembling the supposed coral Paleotrochis of Emmons was found by Alfred Dugès in the volcanic rocks of an old eroded cone northeast of Guanajuato in the Santa Rosa Mountains. The explanation is suggested that in the upward passage of superheated siliceous waters through the rock a point might be reached where a sudden loosening of the texture would permit a rapid upward radiation of the heat, while below the point the temperature would remain nearly constant for long periods. Deposition would take place wherever a cavity existed, but the supply of silica would be furnished only as it was abstracted by solidification. It is considered that the cavity would be increased in size by the crystallization, and that "the accretion-surface would increase with the lengthening of the cone by the separation of the apices of the cones, consolidation taking place at the point of meeting of the solidified silica with the water, and the water reaching that point slowly."

Origin of Paleotrochis. BY J. S. DILLER. *Am. J. Sci.*, 157, 337–342.—A summary of the reviews of previous writers, and descriptions of both the macroscopic and microscopic characters of specimens from Mexico (see preceding review), and from the San Christian Gold Mine of North Carolina are given in some detail. In both cases the Paleotrochis occurred in igneous rock, the analysis of the North Carolina type, which is given in full, indicating a rhyolite. The more perfect Paleotrochis are composed of granular quartz and were deposited within the more or less elongated spherulites with which the rock abounds, but whether this deposition followed soon after that of the spherulites in the course of consolidation, or took place in hollow spherulites (lithophysae), or were the result of subsequent alteration, is not clear. The biconical forms suggest that they may have originated as two spherulitic sectors, of which the apices were the centers from which the growth started.

On the Association of Argillaceous Rocks with Quartz Veins in the Region of Diamantina, Brazil. By Orville A. Derby. *Am. J. Sci.*, **157**, 343–356.—The paper discusses in detail the characters and probable origin of certain more or less strongly decomposed rocks of the Diamantina district. An exhaustive analysis of a cyanitic schist from the region in question, made by W. F. Hillebrand, is included.

Goldschmidtite, a New Mineral. By William H. Hobbs. *Am. J. Sci.*, **157**, 357–364.—The new mineral, to which the name of goldschmidtite has been given by the author, is a brittle, silver-white substance, having a hardness of about 2 and a specific gravity of 8.6. It is found in the form of minute columnar monoclinic crystals attached to the chalcedonic coatings of the fragments of a brecciated igneous rock of the acid type occurring at the Gold Dollar Mine, Arequa Gulch, Cripple Creek. The analysis shows the presence of 31.41 per cent. of gold, 8.90 per cent. silver, and 59.64 per cent. tellurium, corresponding to the formula Au_2AgTe_6, and giving it a position intermediate between calaverite and sylvanite. Twenty-two crystal forms were recognized, ten of which are also recognized in sylvanite, to which the new mineral is most closely allied.

On a Hydromica from New Jersey. By F. W. Clarke and N. H. Darton. *Am. J. Sci.*, **157**, 365–366.—This golden-bronze mineral, which differs widely from any hitherto-described mica, is found mainly as thin coatings in veins of calcite adjacent to the diabase wall rock at Rocky Hill, N. J. The analysis indicates an orthosilicate of the formula

$$(KH)_{.88}(MgFe)_{.24}(AlFe)_{.81}(SiO_4)_{.67}.28H_2O,$$

pointing to a mixture of muscovitic ($R'''(SiO_4)_3R'_3$) and phlogopitic ($R'''(SiO_4)_3R''_3H_3.3H_2O$) molecules in the ratio of 9 to 5.

METALLURGICAL CHEMISTRY.

H. O. Hofman, Reviewer.

Porous Castings and Occluded Gases. *J. Am. Foundrymen's Assoc.*, **6**, 18.—The paper discusses the effects of hydrogen and sulphur dioxide in castings of brasses and bronzes and of carbon monoxide in castings of steel and suggests some methods for getting rid of occluded gases.

Phosphor Bronze—a Description of Its Characteristics and Methods of Manufacture. By L. S. Smith. *Am. Eng. and R. R. J.*, **73**, 147–149.—The author distinguishes high tensile bronze, the alloy of copper, tin, and phosphorus, and bearing bronze, the above alloy to which lead has been added. He gives

a brief history of the manufacture, the compositions and specifications of the alloys, discusses the action of phosphorus in bronze, the foundry treatment of the alloy, and the method of introducing the phosphorus.

The Progress of Metallography in 1898. By A. Sauveur. *The Metallographist*, **2**, 1–8.

The Microstructure of Bearing Metals. By G. H. Clamer. *J. Franklin Inst.*, **146**, 138–153.—The two leading requirements of bearing alloys, *viz.*, good antifriction and good bearing qualities, depend not only upon the chemical composition but also upon the structure of the alloy. The author discusses three white-metal alloys (having the composition, Pb, 80.00; Sn, 4.75; Sb, 15.00; Bi, 0.25: Pb, 70.00; Sn, 10; Sb, 20: and Sn, 80.00; Sb, 10.00; Cu, 10.00), miscellaneous alloys (with over 60 per cent. of copper, the rest consisting of Zn, Sn, Pb, Sb, etc.), a copper-tin alloy (composed of 7 parts Cu to one part Sn once used in railroad cars, but now abandoned), and phosphor bronze (Cu, 78.72; Pb, 9.89; Sn, 10.58; P, 1.04, which, after remelting, gave Cu, 80.39; Pb, 8.35; Sn, 10.40; P, 0.87), with copper-tin-lead alloys, the last two being commonly used for locomotive journal bearings.

A Study of the Microstructure of Bronzes. By A. E. Outerbridge, Jr. *J. Franklin Inst.*, **147**, 18–31.—The author having examined microscopically a large number of specimens of bronze cut from small castings found that the appearance of the etched surfaces varied greatly with the length of time that they had been exposed to the acid and suggests that a uniform system should be adopted so as to permit satisfactory comparisons.

The Reduction Works for Silver Ores at Aduana, Sonora, Mexico. By M. T. Armas. *J. Franklin Inst.*, **146**, 293–302; 349–357.—The paper is a description of the metallurgical treatment of the complex ores at the works. The ores are of four kinds: 1. Smelting ores, argentiferous gray copper with some blende and galena: SiO_2, 36.2; Cu, 11.4; Pb, 9.8; CaO, 1.8; Fe, 2.1; S, 10.8; Zn, 11.5; Sb, 6.3; As, 5.2; As_2O_3, 1.2; Ag, 2.4. 2. Black ore, a complex mixture of galena, blende, copper glance, chalcopyrite and sulphantimonides and arsenides with more or less silver: SiO_2, 41.4; Cu, 11.4; Pb, 9.8; CaO, 0.8; Fe, 3.1; S, 11.3; Zn, 13.2; Sb, 4.2; As, 3.3; Ag, 1.07. Also plomores, similar to black ore, only richer in lead: SiO_2, 33.2-33.0; Pb, 30.6-28.1; Cu, 6.8-8.0; Zn, 11.5-16.3; S, 12.2-11.1; Sb, 2.1-1.2; As, 2.6-0.9; Ag, 0.60-0.88. 3. Milling ores, siliceous, especially rich in blende: SiO_2, 66.20; Al_2O_3, 0.30; Fe, 4.00; CaO, 1.80; MgO, trace; Zn, 9.35; Cu, 3.82;

S, 6.76; Pb, 4.60; Sb, 1.20; As, 0.84; Ag, 0.22 (ranging from 48 to 72 oz. per ton). 4. Concentrating ores, mixed sulphides assaying 23 oz. silver per ton. The concentrates obtained by wet-stamping and passing over Frue vanners with corrugated and plane belts, have the following composition: SiO_2, 12.0; Pb, 19.1; Cu, 12.1; S, 22.2; Zn, 21.0; Al_2O_3, 1.2; CaO, 0.9; Sb, 3.2; As, 4.1; Fe, 2.9. There are two methods of treatment, chlorodizing roasting followed by leaching with hypo salt and matting with incidental liberation of lead to be cupelled and serving to work up the sulphides from the leaching plant. The hand reverberatory furnace used for chlorodizing has four hearths, 4×9 feet, the ore charge of 1200 lbs. remains 2-3 hours on a hearth, the salt (4–8 per cent.) is added on the last hearth two hours before drawing. An addition of one per cent. pyrite greatly facilitates the chlorodizing roast of ores low in sulphur, the chloridation assay giving 97.5 per cent. soluble silver. The 9 leaching tanks of the plant are 20 feet in diameter and 5 feet deep; they have a gravel filter one foot deep, and hold each 37–45 tons of ore. In base-metal leaching the wash-water is at first admitted from below and the soluble salts are removed in 15–24 hours. The wash-water is freed from copper and silver by being passed over matte, the copper content of which is raised thereby from 35 to 40 per cent. The silver solvent is a mixture of sodium and calcium hyposulphite of a strength of 0.55–0.60 per cent., the rate of leaching is $2\frac{13}{16}$ in., the average time required for a charge 14 days, and the assay of the tailings 2.57 oz. silver per ton. The three precipitating tanks are 12×6 feet and have each a capacity of 678 cu. ft. The precipitant is calcium polysulphide. It is prepared by filling one tank (8 ft. in diameter by $6\frac{1}{2}$ feet in height) 1 foot deep with water, boiling with live steam, adding first burnt lime (100) then sulphur (70), boiling for 5–6 hours, and decanting the solution (6213 liters) with a storage tank. The residue is again treated with water and steam, but a smaller quantity of reagents (lime 79: sulphur 56) is added, giving a second solution of the same strength and quantity as the first. The residue from the second boiling is discharged onto the sand filter of a second vat (6 ft. diameter by 6 ft. in height) and allowed to dry. It is then exposed to the oxidizing action of the air and leached with water, giving a calcium hyposulphite solution of a strength of 6.2 per cent. The sulphides from the precipitating vats (containing 24 per cent. silver and 31 per cent. sulphur) are treated with lime and boiled to extract the free sulphur before they are worked on the lead-bath of an English cupelling furnace. Treating, for example, 11.75 lbs. sulphides with lime and steam for 1 hour gave 54 liters calcium polysulphide of 2° B., containing 5.380 grams sulphur per liter. The concentrates are formed into bricks, 8×3×1 inches,

with a clay-like mass of weathered rhyolite (SiO_2, 54.0; Al_2O_3, 18.6; Fe_2O_3, 15.4; CaO, 2.2; H_2O, 8.6) and charcoal fines, in the proportion, clay 13 per cent., charcoal 8 per cent., and concentrates 79 per cent. The bricks are air-dried, carefully stall-roasted and smelted for a matte to be concentrated to 40 per cent. copper by retreatment. The argentiferous lead which separates out is cupelled in an English cupelling furnace. The test of the cupel, 46×59 inches, is filled with 1579 lbs. of a mixture of 100 limestone (SiO_2, 10.0; Al_2O_3, 0.8; Fe_2O_3, 3.4; CaO, 47.0; H_2O, 1.8; CO_2, 37.0) and 46 weathered rhyolite (SiO_2, 54.0; Al_2O_3, 18.6; Fe_2O_3, 15.4; CaO, 2.2; H_2O, 8.1) crushed to pass a 4-mesh sieve. It holds 3500 lbs. lead; the blast-pressure is 7 oz. per square inch; the loss in silver in cupelling is only 0.7 per cent., the silver bars being brought to a fineness of 990.

How to Build and Operate an Arrastra. By E. L. Ballou. *Min. Sci. Press*, **78**, 32–34.—This is an illustrated description of the method of erecting a water-power arrastra and of the mode of operating.

The Arrastra and the Stamp Mill. By M. F. Leech. *Eng. Min. J.*, **67**, 466.—The arrastra has always been considered a primitive gold amalgamating apparatus suited for the prospector or the small operator. If the ore is crushed sufficiently fine before it is charged into an arrastra, the working capacity of the latter is greatly increased. Thus at Silver City, Idaho, a 5-feet arrastra treats in 24 hours 5 tons of stamped ore. Three 10-feet arrastras set tandem could treat in 24 hours 30 tons average ore rolled to pass a 10-mesh sieve. Setting arrastras in tandem increases the crushing capacity because the drags and their motion can be adapted to the different kinds of work that the three successive mills have to do. The tailings from such a tandem mill can be readily run to a concentrating machine by thinning the pulp in the last arrastra. If roasted ores are to be amalgamated, a mechanical roaster can discharge continuously hot ore into the first arrastra and any imperfection in the roast be corrected by concentrating after the pulp leaves the third arrastra.

Temperature of Battery Water. By W. F. Drake. *Min. Sci. Press*, **77**, 556.—The author found that if in milling gold ore the temperature of the battery water went below 50° F. it had to be heated, as otherwise the yield in gold would diminish, the best results being obtained with water of 80°-90° F. A smaller amount of quicksilver was then found to be necessary than when the water was cooler.

Temperature of Battery Water. By Mine Superintendent. *Min. Sci. Press*, **77**, 505.—It is usually admitted that a

temperature of 60°–70° F. is best for the water used in battery amalgamation of gold ores, although some millmen claim that it is just as well to have it ice-cold. The paper is a record of some instances in which water above 70° F. gave better results than when below. Thus, in one mill the saving of gold was 90 per cent. with water at 80° F., and only 80 per cent. when at 60° F. The warmer water seemed, however, to increase the greenish film of oxidized copper on the plates, but the squeezed amalgam was richer in gold. At the Virtue mine, Baker City, Ore., battery water at 90° F. had to be used; the saving of gold was very high, 90 per cent. by amalgamation with ore running $12–$16 in gold; less quicksilver was used than with cold water, in fact the amalgam was kept so hard as to have a frosty appearance. This was found to be necessary to prevent any quicksilver from draining off, which probably is the greatest objection to the use of warm water.

The Utica Mine Chlorination Plant. By T. N. Smith. *Eng. Min. J.*, **57**, 467–468.—The ore treated is a concentrate containing 33 per cent. iron, 37 per cent. sulphur, and 30 per cent. calcium carbonate. It is roasted in six long-hearth continuous hand-reverberatory furnaces, 12×80 feet. A furnace holds 4 charges, each weighing 2400 lbs. with 10 per cent. moisture. In the furnace, which has a flat bottom, the charges are kept 2 feet apart. The 30 feet of the hearth near the fire bridge form the finishing hearth. In the rest of the furnace each ore-charge occupies about 15 feet of the length of the hearth. Supposing the finishing hearth to be empty and the sulphur of the charge next to it to be burning, this charge will be spread over the 30 feet of the finishing hearth, the working doors kept open, and no wood burned in the fireplace for about 4 hours. When all the sparks have disappeared, the back half of the charge is moved forward 15 feet and spread over the front half; the fire is started again and kept going for two hours. In the meantime the space of 15 feet made vacant by one-half of the finishing charge is filled by moving down the next following charge, etc. After 2 hours' heating, the finishing charge will have become red-hot and will be drawn, the sulphur of the next following one will have begun to burn when 40 lbs. of salt are added to convert calcium carbonate into chloride and thus reduce later on the consumption of chlorine. When the finished charge has been drawn, the next following one, occupying 15 feet of the finishing hearth, is spread over its entire length of 30 feet. Every 6 hours a charge is drawn and given. The men work in 6-hour shifts, one man working 8 hours to assist in drawing, moving, and charging. A charge of roasted ore, after having cooled, is wetted with 12½ lbs. concentrated sulphuric acid (diluted with

12 per cent. water), mixed and shoveled into a heap in front of a leaching vat. The four leaching vats, made of 2-inch pine, are 8 feet 6 inches in diameter, 3 feet 6 inches high, and have a 6-inch gravel filter. Laths 1½-inch square are placed on the bottom 1 foot apart, across these 6-inch strips, 1 inch apart, next follow flat pieces of rock, then gravel 1 inch in diameter and from 6 to 7 fine sizes of sands; the last one is covered with 4-inch strips used as a shoveling floor, the spaces between them being filled with fine sand. The ore is screened into the vat through a 9-mesh sieve, the gas is admitted for 6–8 hours through three openings in the bottom. The gas is produced in three lead generators, taking together 90 lbs. pyrolusite, 100 lbs. salt, and 200 lbs. concentrated sulphuric acid. After remaining in gas for 48 hours, the ore is leached with water to about fill a settling tank, 8 feet in diameter and 4 feet deep, after which ferrous sulphate will give no reaction for gold; the discharge-hose is now hung up and the tub allowed to stand until next morning, when 1 ton of water is run through, which finishes the leaching. To the gold solution in the settling vat are added 15 lbs. sulphuric acid to separate some sulphates; it is then run into the precipitating vat and the gold precipitated with ferrous sulphate. The gold is given 48 hours for settling, which is assisted by adding 1 oz. of barium chloride, the barium sulphate formed carrying down any float-gold. The extraction of the gold is 90 per cent., its fineness 0.997. Recently liquid chlorine has been substituted for 90 per cent. of the gaseous chlorine, it taking 20 minutes to admit it. The liquid chlorine is received in drums 5 feet long by 10 inches in diameter; a drum weighs 300 lbs., holds 115 lbs. liquid chlorine (under a pressure of 200 lbs.), and replaces 972 lbs. pyrolusite, 1080 lbs. salt, and 2160 lbs. sulphuric acid. The cost of working per ton of concentrates is with gaseous chlorine alone $7.80, with liquid and some gaseous chlorine $6.90.

The Lixiviation of Slimes. By A. James. *Eng. Min. J.*, 67, 378.—The paper makes a comparison between leaching slimes by the use of a filter-press at the Kalgoorie mines, Western Australia, and leaching by circulation of pulp with transfer from vat to vat by means of centrifugal pumps followed by decantation and washing at the Witwatersrand mines, South Africa. In general, it may be said that the filtering process requires less water, but the extraction is less perfect and costs more than the circulation process. With sufficient water, as in the South Africa gold districts, the latter process is the only one used; in the arid region of Kalgoorie the dirth of water has so far made filtering the leading process.

The Electro-Zinc Process, and Experimental Researches Which Led to Its Development. By W. Bettel. *Min. Sci. Press*, **78**, 178; 208.—The author describes some experiences that he had in treating fine gold-bearing slimes with potassium cyanide and a filter-press. The slimes containing about 0.3 oz. gold per ton were pulped with a 0.2 per cent. cyanide solution to which potassium permanganate (0.1 lb. per ton of dry slimes) had been added as an oxidizing agent, passed through a Johnson filter-press with 24-inch frame, and then washed. The extraction of gold based on the assay of the tailings was 98.2 per cent. The author has improved the ordinary Johnson press so that by a single movement the different plates are separated a sufficient distance to allow a rapid removal of the slime cakes. In searching for means to clarify dilute cyanide solutions from slimes so as to be able to decant them, the author found that hydroxides which form insoluble compounds with silica, such as those of calcium, strontium, and barium, worked satisfactorily. In large-scale work, of course, only calcium hydroxide is available. In following this method of clarifying, he found that float-gold (Zsigmondi's colloidal gold) was carried down with the slimes, *i. e.*, gold so finely divided that when prepared chemically it would give water a pink color. Tests showed that a solution which, after passing through Pasteur-Chamberland filtering candles, would assay 1 grain gold per ton would, after clarifying with calcium hydroxide, assay only 1½ grains. In order to determine by a quick assay the value of gold in dilute cyanide solutions, the author took samples of from 200 to 1000 cc., shook them for 20 minutes in stoppered flasks with from 5 to 20 cc. sodium amalgam containing 0.1 per cent. sodium, treated the quicksilver separated from the solution with nitric acid until a small globule remained and parted this carefully. Comparative tests proved that the method was accurate to 98–95 per cent. with a solution containing 1 oz. to 5 dwts. of gold, to 95–90 per cent., with a solution of 5 to 1 dwt.; and to 90–80 per cent. with a solution of 1 to 0.1 dwt.; with the last solution it was advisable to take 2500 cc. and 10 cc. sodium amalgam. By applying the necessary corrections values were obtained which were accurate within 2 per cent. of the truth. In experimenting on the electrical precipitation of gold from cyanide solutions the author tried sodium amalgam, which worked very well at first, only 1.5 grains gold per ton being left in a solution containing 1 oz. per ton, but the rapid decomposition of water accompanied by the oxidation of the zinc soon rendered the reagent useless for a weak solution. The idea of producing a galvanic couple by coating the usual zinc shavings with copper, lead, bismuth, and silver, respectively, as suggested by Gladstone and Tribe by dipping them into the solutions, was carried out in a 100-ton ex-

perimental plant. As long as the solutions were clear and the couples clean, the precipitation was most satisfactory; even charcoal did satisfactory work as long as the hydrogen remained occluded in its pores. After some time, however, the precipitation began to slacken and then to stop, the causes of which were to be found in the combined effects of the oxidation of zinc and its precipitation as hydroxide, carbonate, and complex ferrocyanide, the precipitation of lime as carbonate and the settling out of slimes. The electrical precipitation by local action having proved a failure, the author used an extraneous source of current and a special form of cell. Carbon anodes, either plain or coated with platinum sponge, had to be given up as they soon became disintegrated. Lead in an alkaline solution became coated with a non-adherent oxide and the peroxide of lead plates, as used in accumulators; he did not feel justified in using them on account of difficulty of handling and expense. They are, however, strongly recommended by Andreoli (*this Rev.*, 4, 78). A varnished lead plate finally proved satisfactory for the current of 0.4 amperes per square foot of anode area. The varnish consisted of 1 vol. linseed oil (boiled with litharge), 2 vols. Brunswick black (solution of asphaltum in turpentine) and one-third vol. graphite, and the whole diluted with turpentine to thin the mixture; two coats were required. As a diaphragm 14-oz. cotton duck made waterproof with either tannates or chromates of albumen or gelatine was very satisfactory. In order to make the solution passing by the anodes conductive, 0.02 per cent. carbonate of soda was added; the gold solution passing by the cathode was already a conductor. The cathode zinc shavings were held in cages of perforated sheet-zinc having a perforated central division wall and six trays of similar character, the whole being enclosed in a bag. The precipitating box had 90 compartments, 50 narrow (4-inch) and canvas-framed for the anodes and 40 wide (13-inch) for the cathode cages. At the head of the box the solution, made alkaline with sodium carbonate, flowed into the anode divisions, the gold solution into the cathode divisions. The current averaged 200 amperes and 6 volts. It is expected that the resistance in future plants may be overcome by 3 volts. The precipitation was satisfactory throughout; the clean-up was made by treatment with sulphuric acid, followed by fusion with alkali fluxes. The author believes that his process will give at least 6 dwts. more profit per ton of slimes than any other.

A Blast-furnace Problem with Zinc. By W. W. Taylor. *Eng. Min. J.*, 67, 469.—The iron ores smelted in western Virginia containing about 0.1 per cent. zinc form hard cadmias at the throat of the furnace and dusty oxides in the stoves, flues,

etc. A hard, strong cadmia had the following composition: Zn, 73.00; SiO_2, 2.50; FeO and Al_2O_3, 3.00. With slow driving and a large percentage of fuel, little trouble occurs from the presence of zinc; with hard driving and a low consumption of fuel the zinc accretions near the throat of the furnace have to be removed every few months. It has been found that the cadmias collect especially opposite the down-take; in order to prevent their forming large accretions which greatly disturb the running of the furnace and render their handling difficult when broken off, the gases are drawn off by four flues. The cadmias fill the intervening spaces, their weights rarely exceeding 12 tons.

The Whiting Process for Making Portland Cement. By C. Kirckhoff. *Iron Age*, **63** (**No. 10**), 9.—The process aims to make Portland cement from the iron blast-furnace slag of the Illinois Steel Co. A plant producing 500 barrels a day having proved successful at the "North Works," another with a daily capacity of 1500–2000 barrels for the "South Works" is being erected. The liquid slag running from a trough is granulated by a stream of water issuing from a nozzle under a pressure of 80 lbs. to the square inch; it is then conveyed to a rotary dryer, thence to Griffin pulverizers, and lastly the dry pulp to Davidson tube-mills. A tube-mill consists of a horizontal cylinder, 4 feet in diameter and 16 feet long and lined with porcelain, making about 27 revolutions per minute. It is filled to half its volume with flint pebbles, 1–2 inches in diameter, which grind up and mix intimately the pulverized slag, burnt lime and other ingredients making up the charge. This is fed through the trunnion at the upper end and discharged at the periphery at the lower end. At least 95 per cent. of the mixture, the finished cement, will pass a screen with 40,000 meshes to the square inch.

Cast Iron. By R. G. G. Moldenke. *The Foundry*, **13**, 222–231; **14**, 14–16.—The paper gives a general review of the different pig irons used in casting, of the cupola and reverberatory methods of melting, and of the physical and chemical properties of cast iron. Cast iron is defined as an iron carrying over 1½ per cent. silicon, which, after casting, is not subjected to further heat treatment.

The Melting-point of Cast Iron. By R. Moldenke. *J. Am. Foundrymen's Assoc.*, **5**, 282–292.—On account of the difficulty of judging the temperatures of melted irons of different chemical compositions by the eye alone (*e. g.*, a ladleful of one iron, appearing as hot as melted steel while in reality it is cooler than one which seems to be dull-red), induced the author to deter-

mine the melting temperatures experimentally. He used the LeChatelier pyrometer, modifying it by covering the exposed couple with a fire-clay tip. This can be attached to the iron pipe holding the platinum and platinum-rhodium wires, insulated in this case with asbestos. Using the tip, a correct reading is obtained in 1¾ minutes, when the couple is plunged cold into the liquid metal; if it is first brought to a red-heat this can be done in a few seconds. The melting-points of 73 samples of analyzed pig iron, ferro silicon, silico-spiegel, cast iron, and alloys of steel were determined and tabulated by the author.

Method of Casting Test-bars for the American Foundry Association Testing Committee. By T. D. West. *J. Am. Foundrymen's Assoc.*, **5**, 301–305.

The Yard-Grading of Pig Iron. By W. B. Phillips. *J. Am. Foundrymen's Assoc.*, **6**, 6–17.—In grading pig iron for foundry purposes according to the appearance of the fracture there are distinguished at present the following 13 classes: Open and close silver-gray irons show a fine silvery luster on a fresh surface, are flaky, have little or no granulation, are weak, and contain 5–6 per cent. silicon. Nos. 1 and 2 soft irons begin to show granulation, have light color, a smooth surface, and a weak fraction, the Si ranges from 3–4 per cent., they are less flaky than silvery irons, less jagged than foundry irons, and darker than silvery irons on account of the graphite they contain. No. 1 foundry is dark, has a granulation that is very open and regular, its crystallization is well marked, and the face is rough to the feel, the Si runs from 2.50–3.00 per cent. No. 2 foundry has the same general character as No. 1, it is closer grained, shows a finer crystallization, and while the color may be the same as in No. 1 it lacks the blackish-gray velvety quality, the Si runs from 2.25–2.50 per cent.; No. 3 foundry with 2.00–2.25 per cent. and No. 4 foundry with 1.75–2.00 per cent. silicon form the transition to gray forge with 1.50–1.75 per cent. This has a pebbled granulation in the center with mottled edges, the face is blistered, pitted and often honeycombed. Mottled iron with 1.25–1.50 per cent. silicon has next to no granulation, but shows a pepper-and-salt appearance on a fresh fracture. Finally, white iron has no granulation whatever, is white but not silvery, the silicon runs from 0.1–0.6 per cent. The author shows how unsatisfactory is the present method of grading, when *e. g.* silvery irons are hardly produced at all and the silicon irons, which formerly analyzed 3–5 per cent., now carry 2–3 per cent. silicon without having changed their appearance correspondingly so as to allow a satisfactory grading by fracture. Grading alone by the silicon content is simple, but

unsatisfactory ; to it ought to be added a ratio between silicon and combined carbon for soft and foundry irons and the percentage of sulphur as affecting gray forge, mottled, and white irons. This brings the grading nearly to a chemical basis. The use to which a particular pig iron is to be put is indicated by its chemical composition and not by its color, fracture, granulation of fracture, etc. In large works which have uniform ore charges, the outer appearance may serve as a guide, if it is continually checked by work in the chemical laboratory. Retaining the old nomenclature, the author proposes the following six grades, with the understanding that in special cases the percentage of phosphorus be also included :

Kind of iron.	Si.	Comb. C.	S.
Silvery	5–6	0.10–0.30	0.01–0.04
Soft	3–5	0.20–0.60	0.01–0.05
Foundry	2–3	0.30–0.90	0.01–0.07
Gray Forge	1–2	0.40–1.25	0.04–0.09
Mottled	0.6–1	0.50–1.80	0.06–0.11
White	0.1–0.6	1.00–2.50	0.08–0.30

On the Influence of Silicon upon the Heat of Solution of Coke Cast Irons. By E. D. Campbell and W. E. Hartman. *J. Am. Chem. Soc.*, **20**, 690–695.—The metallurgical interest of this paper lies in the question as to whether the form of silicon in which it is present in No. 1 foundry iron changes when with increase of temperature a blast-furnace produces lighter and lighter irons until silvery or glazed iron is made, which shows such different physical and chemical properties from No. 1 foundry. The conclusions arrived at are that in dissolving iron with 0.1–0.4 per cent. silicon and the carbon nearly all present in the graphitic form, the heat evolved by the oxidation of the silicon is proportional to the amount of silicon present. With low-silicon iron in which the carbon is largely present in the combined state, the heat made sensible by solution is much diminished owing to the heat consumed in decomposing iron-carbon compounds and possibly some compounds of iron, silicon, and carbon, or of carbon and silicon. Since the oxidation of 1 gram silicon evolves 3824 calories, and the maximum of calories evolved in dissolving cast irons in the experiments was 3303 calories, it is evident that the decomposition of the compounds of silicon with iron must consume a large amount of heat. Lastly, ferrosilicon, in which the percentage of silicon is nearly sufficient to correspond to the formula $SiFe_2$ is not decomposed by ammonium copper chloride.

The Allotropic Theory and the Hardening Power of Low-Carbon Steel. By H. M. Howe. *The Metallographist*, **2**, 77–78.—An answer to Ledebur's discussion of the author's experiments on the hardening of low-carbon steel.

ANALYTICAL CHEMISTRY.

ULTIMATE ANALYSIS.

W. H. WALKER, REVIEWER.

The Volatilization of the Iron Chlorides in Analysis and the Separation of the Oxides of Iron and Aluminum. BY F. A. GOOCH AND FRANK S. HAVENS. *Am. J. Sci.*, **157**, 370–374.—When ferric oxide is submitted to the action of dry hydrochloric acid gas at a temperature of 180°–200°, it volatilizes partially as ferric chloride, but leaves ultimately a crystalline residue of ferrous chloride not volatilized at even 500°. If, however, the oxide be first heated to 450°–500° before the brisk stream of hydrochloric acid gas begins to act, or if the acid contains a little chlorine when it is passed over at 200°, the entire mass of oxide is converted and volatilized without residue. Results of experiments to apply this principle to the separation of the mixed oxides of iron and aluminum are perfectly satisfactory, showing that the separation of the iron oxide is complete at 450°, when the mixed oxides are submitted at once to the action of the gas, or at 200°, when chlorine is mixed with the acid gas.

The Use of Compressed Oxygen in Elementary Organic Analysis and of Soda-lime in the Quantitative Determination of Carbon Dioxide. BY FRANCIS G. BENEDICT AND OLIN F. TOWER. *J. Am. Chem. Soc.*, **21**, 389–398.—Inasmuch as oxygen stored under pressure in steel cylinders was found to contain less moisture and carbon dioxide than that made in the ordinary way and used from a gasometer, the author considers the use of the compressed gas an advantage in elementary organic analysis, and describes a piece of apparatus by the use of which the pressure of the gas may be controlled. Freshly prepared soda-lime was found to lose less moisture during absorption of carbon dioxide than potash bulbs.

Determination of Calcium and Magnesium in Ashes. BY J. K. HAYWOOD. *J. Am. Chem. Soc.*, **21**, 508–511.—Instead of filtering off the basic acetate precipitate containing the iron and phosphoric acid and washing it free from the filtrate in which calcium and magnesium are to be determined, the author finds it sufficiently accurate to filter only an aliquot part of the supernatant liquid and to precipitate the calcium and magnesium from this. Analytical data are given to show the accuracy of the process.

Tests for Boric Acid. BY VICTOR LENHER AND J. S. C. WELLS. *J. Am. Chem. Soc.*, **21**, 417–420.—An experiment

described by Newth in his "Chemical Lecture Experiments" for the production of boric ether is applied as a qualitative test for boric acid. It is found more delicate than the usual method of sulphuric acid and alcohol in an evaporating dish. It is carried out as follows: In a test-tube fitted with a cork, through which passes a glass tube drawn out to a jet, are placed the borate, sulphuric acid, and alcohol. The boric ether formed when the mixture is heated burns at the jet with the characteristic flame, copper and barium not interfering with the test. Comparative tests of all the ordinary methods, however, show turmeric paper to be the most sensitive.

The Constitution of the Ammonium Magnesium Phosphate of Analysis. By F. A. Gooch and Martha Austin. *Am. J. Sci.*, 157, 187–198.—The results of this extended investigation show that in determining magnesium by the procedure in ordinary use, the tendency is strong towards too high results, and it is made evident that the error is due to the combined effect of excesses of the precipitant, the ammonium salt, and free ammonia in throwing down a compound of phosphoric acid richer in ammonia and poorer in magnesium than the normal salt, NH_4MgPO_4. This tendency is counteracted, and the consequent error entirely eliminated, by pouring off the supernatant liquid (through the filter subsequently to be used to collect the precipitate) as soon as the precipitate subsides, dissolving the phosphate in the least amount of hydrochloric acid, and after dilution reprecipitating by a faint excess of ammonia. This procedure precipitates the normal salt, which should be washed with faintly ammoniacal water. In the precipitation of a soluble phosphate by magnesium mixture the results are much the same, and the use of strong ammonia (1 : 3) is again shown to be not only unnecessary but disadvantageous. Good results may be expected when the solution of the phosphate containing a moderate excess of a magnesium salt and not more than ten per cent. of ammonium chloride is precipitated by making slightly alkaline, and then washed with slightly alkaline wash-water.

A Modification of Pierce's Method for the Determination of Arsenic in Ores. By J. F. Bennett, Jr. *J. Am. Chem. Soc.*, 21, 431–435.—The modifications consist essentially in substituting acetic acid for a mineral acid when neutralizing the solution of the alkaline fusion, and using phenolphthalein as indicator instead of litmus. The details of the improved method are given in full, and to these are added many analytical data.

The Influence of Hydrochloric Acid in Titration by Sodium Thiosulphate, with Special Reference to the Estimation of Selenious Acid. By John T. Norton, Jr. *Am. J. Sci.*, 157,

287–293.—In the iodometric method for the determination of selenious acid of Norris and Fay (*this Rev.*, 4, 31) it was found that the presence of hydrochloric acid did not influence the results providing the reaction took place at the temperature of melting ice. By titrating decinormal solutions of sodium thiosulphate and iodine in the presence of hydrochloric acid under varying conditions of temperature, concentration of acid, and excess of thiosulphate present, the author finds that without certain precautions the presence of hydrochloric acid influences the results very considerably. If the excess of thiosulphate be not more than 20 cc., however, and the concentration of acid be not greater than 10 cc. of hydrochloric acid (sp. gr. 1.12) in 400 cc. of solution, the above process is shown to be very accurate.

The Titration of Oxalic Acid by Potassium Permanganate in the Presence of Hydrochloric Acid. By F. A. Gooch and C. A. Peters. *Am. J. Sci.*, 157, 461–467.—Although it has been stated by several investigators that hydrochloric acid does not interfere with the titration of oxalic acid by potassium permanganate, the authors give experimental data which go to show that the error introduced by the presence of hydrochloric acid is very appreciable. As is the case with the oxidation of ferrous chloride, however, the presence of a suitable amount of a manganous salt entirely prevents the action of the permanganate on the acid.

On the Determination of Sulphur in Sulphites. By A. Bourgougnon. *J. Am. Chem. Soc.*, 21, 469–470.—The sulphite in dilute hydrochloric acid solution is treated with a solution of hydrogen peroxide, and the sulphuric acid formed is precipitated and weighed as barium sulphate.

PROXIMATE ANALYSIS.

W. H. Walker, Reviewer.

Estimation of the Lime, Potash, and Phosphoric Acid in Hawaiian Soils Probably Available for the Immediate Crop. By Walter Maxwell. *J. Am. Chem. Soc.*, 21, 415–417.—In order that the lime, potash, phosphoric acid, and other bases may be dissolved from the soil in the proportion that they are removed by "cropping," the sample is treated with a one per cent. solution of aspartic acid for twenty-four hours. This solution is then evaporated, and the residue is ignited and analyzed by the usual methods.

Notes on the Analysis of Dynamite and Gelatine-Dynamite. By F. W. Smith. *J. Am. Chem. Soc.*, 21, 425–431.—Procedures for the analysis of explosives containing nitroglycerine are

given in detail, together with the results of several analyses which may be considered typical of this class of products.

ASSAYING.

H. O. HOFMAN, REVIEWER.

The Assay of Telluride Ores. BY C. H. FULTON. *School Mines Quart.*, **19**, 419–426.—This paper gives the results of crucible and scorification assays made on two Cripple Creek gold ores assaying about 5 and 450 oz. gold per ton. They show that the crucible assay is to be preferred by far to the scorification method; that in the crucible assay an excess of litharge has a beneficial effect; that the lead-buttons weighing 20–28 grams must be malleable so as to permit direct cupelling and not necessitate any scorification, which is connected with large losses; that the slags carry off considerable gold and have to be reassayed; and that the absorption by the cupel need not be taken into account.

GEOLOGICAL AND MINERALOGICAL CHEMISTRY.

W. O. CROSBY, REVIEWER.

The Petrographical Province of Essex County, Mass. BY HENRY S. WASHINGTON. *J. Geol.*, **6**, 787–808; **7**, 53–64, 105–121, 284–294.—Although Essex county is a region of great petrographic diversity and interest, and its rocks have received much attention from geologists in the past, and are the subject of a considerable literature, this series of papers is the first systematic and comprehensive petrological study of this now classic area. The author confines his attention to the igneous rocks, which include chiefly granites, quartz-syenites, syenites, nepheline-syenites, essexites, diorites, and gabbros, cut by numerous dikes and with later flows of rhyolite. The entire series is regarded as pre-Carboniferous and post-Cambrian, having cut and metamorphosed the Cambrian strata of the region. The descriptions are supplemented by chemical analyses and a general discussion of the results, including a comparison of this region with others of similar character. The *granites* are all hornblendic, but contain also more or less glaucophane and biotite, and the accessories include danalite, fayalite, allanite, epidote, zircon, magnetite, apatite, fluorite. The feldspar is all of the most acid alkali varieties, including orthoclase, microcline, and albite, occurring largely as highly typical microperthites and cryptoperthites. The analysis shows a typical acid granite, rich in potash and low in lime and iron oxides. The mineralogical composition, as for most of the rocks studied, is calculated from the analysis. Included masses of darker color and finer grain

are found to consist of the same essential minerals as the granite, but in different proportions, analysis showing 10 per cent. less silica and much more iron oxide, corresponding to a *quartz-syenite*. *Akerite*, or *augitic quartz-syenite* is found to be almost as abundant as the granites, and the analysis shows it to be closely similar in composition to the dark inclusions of the granite, and like these it is regarded as a differentiation of the granite magma. Another very slight differentiation is afforded by the *nordmarkite* or *mica-hornblende-quartz-syenite*, and the more acid character of this type finds mineralogical expression in the substitution of biotite and hornblende for augite. More strongly contrasted with these, and with an unquestionable claim to separate recognition is the *nepheline syenite*, which has, in comparison, a rather limited development. Two main structure types are recognized, a granitic and a trachytic, which shade into each other and correspond to the *ditroite* and *foyaite* of Brögger, the latter predominating. An analysis is given for each type, the only notable difference being that the foyaite is rather richer in soda and poorer in iron oxide than the ditroite, while both are notably poorer in lime and magnesia than the nepheline syenites of other regions, and higher in silica than the average, agreeing closely with the albite-rich litchfieldite of Bayley. Next comes, as a facies of the nepheline syenite, and showing the same structural distinction, the nepheline-poor to nepheline-free rock known as *pulaskitic syenite* or *pulaskite*. An analysis of each phase of this rock shows that it is decidedly more acid than the normal type of nepheline syenite. This series closes with the *orbicular syenite*, which occurs as rounded inclusions in granite and owes its name to the fact that each prominent phenocryst of hornblende is surrounded by a narrow zone of white feldspar. *Essexite*, described as essentially a basic monzonitic rock containing both lime-soda and alkali feldspars and feldspathoids, is confined to the immediate vicinity of Salem Neck. It is quite distinct from the nepheline syenites, by which it is cut, but grades into the diorites. Sears regards it as the earliest crystallized and most basic portion of the nepheline-syenite magma. Several structural and mineralogical varieties are recognized, and an analysis of a specimen selected by Sears as representing the type shows a decidedly basic rock (SiO_2, 46.99) rich in lime and soda. *Diorite* has a large development in Essex County. It is highly varied and represents transitions from the essexites to the akerites. The analysis shows a rather basic rock for a diorite (SiO_2, 51.82), but, on the other hand, both the silica and alkalies are too high for a gabbro. Besides the main type of diorite, which is often more or less quartzose, the author describes a *quartz-augite-diorite* and a *porphyritic diorite*, with an analysis of the latter. The *gabbro* of Nahant is next described,

and the analysis shows that it is low in silica (43.73) and rich in lime (10.99) as a gabbro should be, but also rather poor in magnesia, high in titanium oxide and alumina, and rather high in alkalies, for a gabbro. The hyperitic essexite of Rosenbusch, called also hyperitic diorite in one of the earlier papers of this series, is shown by a later analysis to be more properly a *hornblende gabbro* (SiO_2, 45.32). The dike rocks next receive attention, beginning with the granitic dikes. These include *aplite*, the very narrow dikes of which are wholly confined to the granite, with which they are found to agree closely in composition, and *quartz-syenite-porphyry*, which is found to be essentially identical in composition with the nordmarkite. The rocks of the *paisanite-sölosbergite-tingnaite* series all form dikes, although of *paisanite* but a single dike has been observed, the analysis of which is almost identical with the aplite. The *sölosbergite* forms numerous dikes, which are described in detail, with two original analyses and one quoted from Rosenbusch. Three *tingnaite* dikes are described, with two analyses, the more basic analysis representing an *analcite tingnaite*. The basic dikes include dikes of *camptonite* (one analysis), *vogesite*, very numerous dikes of *diabase* (one analysis), and dikes of *labradorite porphyry* or *porphyritic diabase*. The work closes with a brief account of the extensive rocks, including the *rhyolite* and *keratophyre* of Marblehead Neck, and with an analysis of each.

M. L. FULLER, REVIEWER.

Augite-Syenite Gneiss near Loon Lake, New York. BY H. P. CUSHING. *Bull. Geol. Soc. Am.*, **10**, 177–192.—This is a greenish-gray, massive, igneous rock of cataclastic structure and medium grain, which resembles some phases of the Anorthosites of the region, and was formerly classed with them. It cuts and encloses gneissic rocks which are regarded as unquestionably sedimentary and referred to the Greenville series, and is, in turn, cut by the diabases, the youngest of the pre-Potsdam rocks. The syenite is essentially composed of microperthite, augite, and hypersthene, with quartz always present in varying and commonly slight amount. Other component minerals include zircon, apatite, magnetite, garnet, hornblende, oligoclase, and sometimes biotite, titanite, allanite, and pyrite. The analysis, by E. W. Morley, gives: SiO_2, 63.45; TiO_2, 0.07; Al_2O_3, 18.31; Fe_2O_3, 0.42; FeO, 3.56; MnO, none; CaO, 2.93; BaO, 0.13; MgO, 0.35; K_2O, 5.15; Na_2O, 5.06; P_2O_5, trace; loss, 0.30; total, 99.73. Assuming the augite to be a calcium, ferrous-iron, aluminum silicate, the author calculates from the analysis the proportions of the chief component minerals as follows: Magnetite, 0.73; orthoclase, 30.39; albite, 42.70; anorthite, 4.51; hypersthene, 2.03; augite, 12.02; quartz, 7.07.

This result agrees well with that obtained by separation with heavy solutions. The plagioclase is a nearly pure albite, $Ab_{19}An_2$, and the microperthite is approximately Or_3Ab_5. Six other analyses are quoted for comparison, and the Loon Lake rock is seen to agree very closely with several other syenites, and especially with those of Diana, N. Y., Mt. Ascutney, and Gloucester, Mass., which are all referred to an acid phase of the variety called akerite by Brögger. Other Adirondack localities are briefly described, and the rock is shown to vary within quite wide limits, varying from a granite to a syenite more basic than the one analyzed. The relations of the syenites to the anorthosites are also discussed, the conclusion being that the syenites are probably a result of differentiation in the anorthosite magma after reaching its place of final cooling, and in part are somewhat later in date.

Origin of Grahamite. By I. C. White. *Bull. Geol. Soc. Am.*, **10**, 277–284.—The grahamite of Ritchie County, West Virginia, first described by Lesley in 1863, and more fully by Fontaine in 1873, fills a vertical fissure about two-thirds of a mile long, varying in width from a few inches at the ends to 4 and 5 feet in the middle. The fissure is at right angles to and undoubtedly genetically connected with the Burning Springs-Eureka anticlinal which, with dips of from 30° to 70°, crosses the formation about 7 miles west of the deposit. Lesley predicted that "this gash was once an open fissure communicating with some reservoir of coal oil (petroleum) which still, it may be, lies beneath it undisturbed." Oil wells drilled during the past decade have fully verified this prediction, developing at a depth of 1500 to 1600 feet and in close proximity to the grahamite fissure, a pool of oil which is but part of the prolific Cairo oil field. Hence the author concludes that there can be no doubt whatever that the fissure made by tension from the Burning Springs-Eureka uplift was filled with petroleum from this pool, and that subsequently the oil was gradually converted by oxidation from infiltrating water into grahamite without any heat other than that afforded by the normal temperature of the earth. In this connection he cites Jeaney's experimental production of grahamite by passing heated air through petroleum for several hours. As a corollary from this conclusion, albertite, gilsonite, uintaite, and practically all forms of asphalt, including, as suggested by Diller, the "pitch" coal of Coos Bay, Oregon, are oxidized petroleum, and the wonderful deposit of asphalt on the island of Trinidad is regarded as an old oil pool uncovered by erosion and hardened by volatilization and oxidation.

A Contribution to the Study of Contact Metamorphism. By J. MORGAN CLEMENTS. *Am. J. Sci.*, 157, 81–91.—This paper is essentially a detailed account of a somewhat normal instance of contact metamorphism not hitherto described. It occurs in the Lower Huronian iron-bearing formation of the Crystal Falls district of the upper peninsula of Michigan, where the Mansfield slate formation of the Michiganie Valley is cut by large and continuous masses of coarse dolenite (diabase). The intrusions show no evidence of endomorphic action and are not described; but the slate, which is an undoubted sedimentary deposit, exhibits, as we approach the igneous contact, increasing metamorphism, and the successive phases known as phyllites, tpilosites, desmosites, and adinoles are observed in normal order. The least altered rocks, the normal clay slates, are found on microscopic examination to be of a semicrystalline character, containing, besides elastic quartz and original interstitial matter, secondary white mica, rutile, hematite, and actinolite. The phyllites are similar, except that they are more lustrous, and the interstitial material has been changed to white mica. The spilosites, desmosites, and adinoles are the true contact products. They are dense, flinty, "hornestone-like" rocks, which show in some cases the fine banding of the original slates, while others are very characteristically spotted. The mineralogical components are quartz, feldspar (albite), biotite, chlorite, with emica, actinolite, rutile, epidote, and iron oxide. In the first two varieties chlorite is the chief dark constituent with little or no actinolite, while the opposite relation holds for the adinoles. Complete analyses by George Steiger and H. N. Stokes are given for the normal clay slates, spilosites, and adinoles. A comparison of the analyses shows a marked increase of silica as the dolerite is approached, and a corresponding diminution of alumina and iron as well as of water and carbonaceous matter. The most noteworthy contrast between the clay slate and the contact rocks is shown in the relations of potash and soda. For the clay slate the percentages are 5.73 and 0.54, respectively, while in the contact rocks these proportions are reversed, the successive values for potash being 0.70, 0.22, 0.15, and for soda 6.72, 8.22, 6.57. This agrees with the fact that, while albite is wanting in the clay slate, it is an abundant constituent of the contact rocks. The author concludes that the changes in ultimate chemical composition are probably best explained as due to an actual transfer of material, possibly in the form of a soda silicate, from the basic igneous rock to the intruded slate.

A Contribution to the Geology of the Pre-Cambrian Igneous Rocks of the Fox River Valley, Wisconsin. By SAMUEL WEIDMAN. *Wis. Geol. and Nat. Hist. Survey, Bull. No.* 3,

Science Series No. 2, 1–63.—The areas of igneous rocks described in this paper are a part of the cordon of hills and ridges of pre-Cambrian rocks that lie outside the more continuous crystalline cove of central and northern Wisconsin. These outlying hills were islands in the early Paleozoic seas, and around them are deposited the later horizontal formations of sandstone and limestone. Among the pre-Cambrian outliers are to be found rocks of both sedimentary and igneous origin; but those of the Fox River district are wholly igneous, of both plutonic and volcanic nature. Three types are described in great detail, *viz.*, the Utley metarhyolite, Berlin rhyolite-gneiss, and Wanshara granite. They are regarded as of Keweenawan age, and the close agreement of the bulk analyses shows that they are essentially consanguineous and belong with the Baraboo rhyolite to a petrographic province of considerable extent. The acid character of these rocks limits the mineral composition chiefly to quartz and feldspar. An analysis of the feldspar phenocrysts of the Utley metarhyolite shows that they are a soda-lime feldspar with a considerable amount of potash; and in harmony with this composition, the microscope reveals in most cases a micropesthitic structure. This is discussed at some length and shown to be partly original and partly secondary; and the latter is believed to be due in part to an enlargement or outgrowth of the original plagioclase phenocrysts, and in part to intergrowths or regeneration of older plagioclase, the latter process being regarded as allied to paramorphism and not unlike the process of schillerization as described by Judd.

On Hardystonite, a New Calcium Zinc Silicate from Franklin Furnace, New Jersey. By John E. Wolff. *Proc. Am. Acad.*, 34, 479-481.—This is a granular, white, vitreous mineral which is intimately associated with the willemite, rhodonite, and franklinite of the zinc mines. The crystallization is tetragonal with a good basal cleavage and secondary cleavages parallel to the prisms of the first and second orders. The specific gravity is 3.95, and hardness between 3 and 4. The analyses, recalculated to 100 and omitting iron and ignition as non-essential, give as the normal composition: SiO_2, 38.34; ZnO, 24.45; MnO, 1.50; CaO, 34.07; MgO, 1.62. The molecular ratios give (ZnMn)O : (CaMg)O : SiO_2 as 1 : 2 : 2, with Mn to Zn and Mg to Ca as 1 to 15; and the formula is hence $(ZnMn)O,2(CaMg)O,2SiO_2$ or $ZnO,2CaO,2SiO_2$, the theoretical composition of the latter being: SiO_2, 38.34; ZnO, 25.88; CaO, 35.78.

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REVIEW OF AMERICAN CHEMICAL RESEARCH.

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ARTHUR A. NOYES, Editor.
REVIEWERS: Analytical Chemistry, H. P. Talbot and W. H. Walker; Biological Chemistry, A. G. Woodman; Carbohydrates, G. W. Rolfe; General Chemistry, A. A. Noyes; Geological and Mineralogical Chemistry, W. O. Crosby and M. L. Fuller; Inorganic Chemistry, Henry Fay; Metallurgical Chemistry and Assaying, H. O. Hofman; Organic Chemistry, J. F. Norris; Physical Chemistry, H. M. Goodwin; Sanitary Chemistry, E. H. Richards; Technical Chemistry, A. H. Gill and F. H. Thorp.

GENERAL AND PHYSICAL CHEMISTRY.

A. A. NOYES, REVIEWER.

The Theory of the Formation of Nickel Sulphide. BY J. LIVINGSTON R. MORGAN, AND A. H. GOTTHELF. *J. Am. Chem. Soc.*, **21**, 494–502.—The authors attempt to show that the well-known fact that nickel and cobalt sulphides when once formed are not dissolved by acids of a concentration much greater than is required for preventing entirely their precipitation by hydrogen sulphide, can be explained simply by an application of the principles of mass-action and of electrolytic dissociation, assuming an appropriate value for the solubility of the sulphides. The considerations of the authors are, in the reviewer's opinion, erroneous in some essential points (thus this is true of the statements that no undissociated nickel sulphide or hydrogen sulphide will be formed till the product of the concentrations of their respective ions reaches the value of the "solubility-product"), but it is unnecessary to discuss these in detail, since it is *a priori* evident that the principles of equilibrium as ordinarily applied cannot possibly explain the phenomenon in question; for, if equilibrium exist between the four substances, $NiCl_2$, H_2S, HCl, and NiS (solid), when the first two are present in large amount and the last two in very small amount, it is clear that the conditions must be *far* removed from those of equilibrium when the last two compounds are alone brought together, and conversely. The probable explanation, previously suggested by Ostwald (*Scientific Foundations of Analytical Chemistry*, p. 149), of this apparent anomaly, is that after precipitation the nickel sulphide rapidly undergoes a change in its chemical nature (perhaps a dehydration), the new form being

much less soluble in water and therefore in acids than the original one. By quantitative experiments Ostwald has proved that this is the case with zinc sulphide, and the same property, in a much more pronounced degree, seems to be possessed by nickel and cobalt sulphides.

The Effect of Diionic Electrolytes on the Solubility of Triionic Electrolytes with Different Ions. By ARTHUR A. NOYES AND EDWARD S. CHAPIN. *J. Am. Chem. Soc.*, **21**, 511–516.—The authors derive the theory of the phenomenon mentioned in the title and communicate experiments confirming it on the solubility of calcium hydroxide in water and ammonium chloride solutions.

The Theory of the Separation of Barium, Strontium, and Calcium from the Mixed Sulphates. By J. LIVINGSTON R. MORGAN. *J. Am. Chem. Soc.*, **21**, 522–526.—It is shown that the separation of the sulphates named, by ammonium carbonate or a mixture of potassium sulphate and carbonate, is readily explained by the dissociation theory and the laws of solubility-effect.

The Atomic Mass of Tungsten and the Preparation of Sodium Pertungstate by Means of the Electric Current. By GEORGE EDWARD THOMAS. *J. Am. Chem. Soc.*, **21**, 373–381.—In the first part of the article it is shown that two samples of tungsten trioxide, prepared from distinct minerals, scheelite and wolframite, are apparently identical, but that both of them fail to give concordant values of the atomic weight when reduced to the metal or when the latter is reoxidized; also that the method of determining the atomic weight from the loss of weight occurring when crystallized sodium tungstate is heated sufficiently to expel the water is an unsuitable one. In the second part the author describes the results of electrolyzing sodium tungstate, considering that a pertungstate is formed thereby, since a substance liberating chlorine, iodine, and ozone was obtained, though not in a state of even approximate purity.

The Surface-Tensions of Aqueous Solutions of Alkaline Chlorides. By C. E. LINEBARGER. *J. Am. Chem. Soc.*, **21**, 411–415.—Equimolecular solutions of potassium, sodium, and lithium chlorides are found to have the same surface-tension; and their surface-tension is found to be only approximately a linear function of the concentration.

ANALYTICAL CHEMISTRY.

ULTIMATE ANALYSIS.

H. P. TALBOT, REVIEWER.

Carbon Combustions in a Platinum Crucible. BY P. W. SHIMER. *J. Am. Chem. Soc.*, **21**, 557–568.—By means of an ingeniously-devised water-cooled stopper, an ordinary platinum crucible is made to take the place of the usual combustion tube, the combustion taking place in a current of air, and the heat being applied by means of a blast-lamp. The gases, on leaving the crucible, pass over a layer of heated cupric oxide, then over beads moistened with cold water, and finally through the usual absorption apparatus. The results obtained are highly satisfactory, and the time required for the completion of the combustion is small. The original article furnishes details of construction and use which are of unusual interest, and suggest that the apparatus may find other uses beside that in the determination of carbon.

The Determination of Carbon and Hydrogen in Organic Substances Containing Nitrogen. BY O. F. TOWER. *J. Am. Chem. Soc.*, **21**, 596–605.—The author finds that during the combustion of amido compounds, such as urea, hippuric acid, and paratoluidine, no oxides of nitrogen are formed which are absorbed by concentrated sulphuric acid or soda-lime, even in the absence of a copper spiral. The same statement applies to the combustion of nitraniline and dinitrobenzene, but picric acid required the introduction of a copper spiral for the accurate determination of the carbon and hydrogen.

A Volumetric Method for Magnesium. BY RICHARD K. MEADE. *J. Am. Chem. Soc.*, **21**, 746–752.—The magnesium is precipitated as magnesium ammonium arsenate, this precipitate dissolved in dilute hydrochloric acid, after which potassium iodide is added to the solution, and the liberated iodine is titrated with sodium thiosulphate solution. The results obtained are quite satisfactory.

The Estimation of Arsenic in Paris Green. BY THORN SMITH. *J. Am. Chem. Soc.*, **21**, 769–772.—The Paris green is treated with a solution of sodium hydroxide which, in the presence of the arsenite, causes a precipitation of cuprous oxide. This is removed by filtration, and, after acidifying with hydrochloric acid, potassium iodide is added, the liberated iodine is reduced by the cautious addition of sodium thiosulphate, and the arsenite is determined by titration with iodine. (Compare also the "*Volumetric Method for Magnesium*" *above*).

A New Method for the Direct Determination of Alumina in the Presence of Iron, Manganese, Calcium, and Magnesium. By William H. Hess and E. D. Campbell. *J. Am. Chem. Soc.*, **21**, 776–780.—The solution of the chlorides of the metals is made nearly neutral with ammonia, ammonium bisulphite is added to reduce the iron, and then one or two cc. of phenylhydrazine. This precipitates the alumina and the phosphoric acid. The precipitate is washed with a solution of phenylhydrazine bisulphite, and then ignited. Chromium may be separated from iron in the same way.

The Determination of Antimony in Ores. By Thomas Brown, Jr. *J. Am. Chem. Soc.*, **21**, 780–789.—The author gives a detailed account of methods of analysis applicable, in particular, to Mexican ores.

Electrolytic Determination of Zinc in the Presence of Manganese. By Emil J. Riederer. *J. Am. Chem. Soc.*, **21**, 789–792.—The zinc is deposited on a silver-coated platinum dish, from solutions containing lactic acid, ammonium lactate, and ammonium sulphate, and the solution is stirred during the deposition, which requires from four to five and one-half hours for completion. The deposited zinc is free from manganese.

The Determination of Sulphur in Bitumens. By S. F. and H. E. Peckham. *J. Am. Chem. Soc.*, **21**, 772–776.—The authors criticise statements made by E. H. Hodgson (see *this Rev.*, **5**, 10) with respect to the accuracy of his method, and give in detail an account of the deflagration method as practiced by them.

W. H. Walker, Reviewer.

The Estimation of Iron in the Ferric State by Reduction with Sodium Thiosulphate and Titration with Iodine. By John T. Norton, Jr. *Am. J. Sci.*, **158**, 25–30.—Although a great deal of work has been done in the endeavor to estimate iron by reduction with sodium thiosulphate, no satisfactory method has as yet been proposed. The concentration of the ferric solution, the amount of acid present, the excess of thiosulphate used, and the length of time allowed for reduction, all greatly influence the reaction. After a great deal of experimenting the following conditions were found to give the most satisfactory results. The concentration of the iron solution must not be greater than 0.1 gram ferric oxide in 400 cc.; the amount of acid present should not exceed 1 cc. of the strong acid in the same volume; the time of reduction must be as short as possible to prevent progressive oxidation by air; and the excess

of thiosulphate used should, for the same weight of iron, be not less than 15 cc. of a decinormal solution.

The Determination of Tellurous Acid in Presence of Haloid Salts. By F. A. Gooch and C. A. Peters. *Am. J. Sci.*, **158**, 122–126.—In a previous paper (*this Rev.*, **5**, 89) it was shown that the reaction between potassium permanganate and oxalic acid in acid solution is not influenced by the presence of chlorides, provided a quantity of manganous salt be added before titration. This modification is introduced into the method for determining tellurous acid by means of permanganate and oxalic acid. By causing the first oxidation to take place in alkaline solution, and making the final titration of the residual oxalic acid in acid solution in the presence of a manganous salt, the estimation of tellurous acid in the presence of chlorides and bromides was found quite satisfactory. In the case of an iodide, however, the presence of a manganous salt is not sufficient to prevent the action of the permanganate, and iodine is set free. As was shown by Norris and Fay (*this Rev.*, **4**, 31), this free iodine may replace the oxalic acid as a measure of the excess of the permanganate used in oxidizing the tellurous acid, and its amount was determined by the authors by reducing it with standard arsenite solution in the presence of an excess of sodium bicarbonate.

An Iodometric Method for the Estimation of Boric Acid. By Louis Cleveland Jones. *Am. J. Sci.*, **158**, 127–132.—In a volumetric method for the estimation of boric acid (*this Rev.*, **5**, 52) it was found that the addition of mannite to the free boric acid made it possible to determine the acid by titration with standard alkali solution. If the solution is almost saturated with mannite (glycerine does not serve the same purpose), the boric acid is rendered active enough to react with potassium iodide and potassium iodate setting free an amount of iodine equivalent to the metaboric acid present:

$$5KI + KIO_3 + 6HOBO = 3I_2 + 6KOBO + 3H_2O.$$

The iodine may be reduced with standard thiosulphate solution, and the amount of boric acid calculated. The necessary precautions as to concentration and temperature are given, and the results obtained seem very satisfactory.

The Double Ammonium Phosphates of Beryllium, Zinc, and Cadmium in Analysis. By Martha Austin. *Am. J. Sci.*, **158**, 206–216.—The influence which varying conditions of temperature and concentration, excess of precipitant, and amounts of ammonium chloride have on the composition of the resulting insoluble phosphates thrown out of solution by means of sodium

acid phosphate or microcosmic salt, has been studied with a view of determining the utility of the compounds in quantitative analysis. It was found impossible to precipitate beryllium as the true beryllium ammonium phosphate; and no determinations made by weighing the pyrophosphate were sufficiently accurate to be of much value. In the presence of ammonium chloride (10 grams in 100 cc.), zinc ammonium phosphate may be obtained in the ideal condition, and forms the basis of a very accurate method for the determination of zinc. In the case of cadmium the precipitate with microcosmic salt in the presence of the same amount of ammonium chloride is also the true double ammonium phosphate, if it be allowed to stand for several hours before filtering. But there must, in this case, be no excess of ammonia, no free acid, and neither more nor less than the amount of ammonium chloride stated.

Separation of Iron from Chromium, Zirconium, and Beryllium, by the Action of Gaseous Hydrochloric Acid on the Oxides. By FRANKE STUART HAVENS AND ARTHUR FITCH WAY. *Am. J. Sci.*, **158**, 217–218.—The procedure for the separation of iron from chromium, beryllium, and zirconium is the same in the case of each metal, and analogous to that employed by the author (*this Rev.*, **5**, 87) for the separation of iron from aluminum. The results given are very satisfactory.

Methods for the Iron Laboratory. By FRANK L. CROBACH. *Iron Trade Rev.*, **32**, Nos. 24 to 29.—This paper consists of a series of five articles in which "the writer outlines for the benefit of beginners in foundry, steel works, and blast-furnace laboratories the methods he considers preferable."

PROXIMATE ANALYSIS.

A. G. WOODMAN, REVIEWER.

The Assay of Opium: A Supplementary Note. By H. M. GORDIN AND A. B. PRESCOTT. *Pharm. Rev.*, **17**, 244–249.—The authors report an improvement in their process for the assay of opium (*Pharm. Arch.*, **1**, 121; *this Rev.*, **4**, 115), consisting in the use of a more desirable solvent for extracting the morphine and an adaptation to the use of standard acid for the volumetric estimation of the morphine.

The Distinction of True Extract of Vanilla from Liquid Preparations of Vanillin. By WILLIAM H. HESS. *Pharm. Rev.*, **17**, 254–257.—The simplest means of proving the origin of vanilla extract consists in the separation and identification of the characteristic resin of which vanilla beans contain from four

to eleven per cent. Simple tests for coloring-matters, chiefly caramel and certain azo dyes, and an examination of the behavior of the extract upon dilution with water are also found useful.

A New Test for Cocaine. By George L. Schaefer. *Am. J. Pharm.*, 71, 222–223.—In order to determine the freedom of commercial cocaine salts from other coca alkaloids, the author has devised a simple test based on the relative insolubility of the chromates of the coca alkaloids in dilute hydrochloric acid.

Assay of Nux Vomica. By W. O. Richtmann. *Pharm. Rev.*, 17, 208–210.—Attention is called to the necessity of using a greater quantity of decinormal sulphuric acid in testing the evaporated percolate obtained in making fluid extract of nux vomica.

A Contribution to the Chemistry of Butter-fat. By C. A. Browne, Jr. *J. Am. Chem. Soc.*, 21, 612–633.—The author has determined in a number of samples of butter-fat the various physical and chemical constants that are usually determined in the examination of the fat together with a number of those not commonly found. Several of the methods and modifications employed are described in considerable detail.

The Assay of Belladonna Leaves. By Frank X. Moerk. *Am. J. Pharm.*, 71, 320–326.—The author has shortened the time required for the assay of belladonna leaves by using a mixture of 90 parts, by weight, of 95 per cent. alcohol and 10 parts, by weight, of 10 per cent. aqua ammonia for extraction purposes instead of the menstruum usually employed (2 volumes alcohol and 1 volume water).

On Acetic Acid as a Substitute for Ethyl Alcohol in Extracting the Active Principles of some Officinal Drugs. By Edward R. Squibb. *Am. J. Pharm.*, 71, 305–320.—In continuation of his previous work upon this subject, the author has carried out experiments with cinchona, and finds that this drug is readily and completely exhausted, even when in fairly coarse powder, by ten per cent. acetic acid. A detailed procedure for the assay of cinchona is worked out and a description is given of a modified form of siphon extractor which has been found to work successfully.

Newer Observations Concerning the Detection of Blood by Means of the Guaiacum Reaction. By Edward Schaer. *Am. J. Pharm.*, 71, 361–370.—In a previous paper the author has proposed to improve the guaiacum-blood reaction, as ordi-

narily used, by substituting for the usual alcoholic guaiacum solution a five per cent. alcoholic solution of guaiacum resin. The intimate mixture of the coloring-matter of blood and guaiacum resin thus obtained may be preserved for an indefinite time and can at any time be used to exhibit the "guaiacum blue" with hydrogen peroxide or Hünefeld's reagent. A further improvement is now suggested consisting in the use of a solution of chloral hydrate to extract the blood stains. The stains, after being moistened with acetic acid, can be extracted either with a 70 per cent. chloral hydrate solution or with a one per cent. solution of guaiacum in aqueous chloral hydrate containing 70–75 per cent. of the latter. To the blood-guaiacum solution in aqueous chloral hydrate thus obtained is added either hydrogen peroxide solution or Hünefeld's liquid so that the two layers do not mix. The blue zone will appear at the place of contact. The guaiacum-blood test with chloral hydrate can also be applied to the identification of the hemin crystals of blood, which is often of great importance. A solution of guaiaconic acid in chloral solution can be substituted for the ordinary guaiacum solution if desired.

On the Determination of Added Water in Milk. By A. G. Woodman. *J. Am. Chem. Soc.*, **21**, 503–508.—The most successful of the methods for the direct determination of the added water in milk is that based upon the specific gravity of milk from which the casein has been removed. The conditions necessary to obtain concordant results have been studied and tables are given showing the specific gravity of the serum from milks of varying dilution.

Paraffin as an Adulterant of Oleomargarine. By Joseph F. Geisler. *J. Am. Chem. Soc.*, **21**, 605-608.—The amount of paraffin which has been found in oleomargarine varies from 5 to 11.76 per cent. Its presence is clearly indicated by the low specific gravity of the fat. If the amount present is over three per cent. it will separate out when the alcoholic soap solution obtained by the Reichert method is diluted with an equal volume of water. The appearance of the fat under polarized light is shown by photomicrographs.

An Examination of Commercial Flour. By Henry Kraemer. *J. Am. Chem. Soc.*, **21**, 650–663.—The author proposes a microchemical method for the estimation of corn-meal in flour. A number of small samples, about 0.0039 gram each, are treated under the microscope with various reagents, which serve to distinguish the grains. The number of grains of each kind in a given field is counted, the average of several samples being taken.

A Method of Analysis for Canned Condensed Milk. By F. S. Hyde. *J. Am. Chem. Soc.*, **21**, 439–444.—The author describes in detail the method used by him which consists in general in diluting the sample with a known quantity of water until it has about the consistency of cow's milk, weighing out aliquot parts of this stock solution, and applying the ordinary methods of milk analysis. A table of results is appended.

G. W. Rolfe, Reviewer.

The Influence of Temperature on the Specific Rotation of Sucrose and Method of Correcting Readings of Compensating Polariscopes Therefor. By Harvey W. Wiley. *J. Am. Chem. Soc.*, **21**, 568–596.—This important investigation is on the influence of temperature on sugar polarizations between 4° and 40° C. The constant correction factor is in close agreement with those obtained by Andrews and the U. S. Coast and Geodetic Survey, and only slightly less than that given by Landolt and Schönrock. It would seem from the amount of data now at hand that the table of temperature corrections for polarizations compiled by the author could be adopted generally in commercial and scientific work, and it undoubtedly will be. However, the statements of the data given for the light factor of the Ventzke saccharimeter require fuller explanation lest false conclusions be drawn and the work of former accurate observers be discredited. It should have been stated that there are three figures, representing the light factor of the Ventzke saccharimeter, any one of which is correct, according to the conditions of measurement. The one last given by Landolt, 0.3468–9, represents the equivalent of one division of the new Ventzke saccharimeter whose graduation is based on 26.048 grams of cane-sugar dissolved in 100 "*true*" centimeters when this is measured in angular degrees of rotation of the light of a sodium flame made as monochromatic as possible by filtration through a Landolt-Lippich ray filter; but if ninety-nine out of a hundred of the Ventzke instruments in the laboratories of the country were compared in this manner, the factor obtained would probably be 0.3461–2, since practically all of the saccharimeters in common use are graduated for 26.048 grams of cane-sugar in 100 "*Mohr centimeters*" at 17.5° C., an "urnormal" plate on these Ventzke instruments reading some two-tenths of a division higher than its recorded value. Finally if the angular measurement in the last case is made on a Laurent polariscope as is common, or a Wild, both of which instruments use a sodium flame filtered through bichromate only, the factor becomes 0.3455–7. Clearly for the conditions defined these factors are equally correct. By the work of many independent investigators, the third factor seems to be established beyond question as

a reliable constant for the light ray obtained by the Laurent and Wild apparatus, notwithstanding that Landolt and Lippich have pointed out that defective construction is more liable to make the Laurent instrument inaccurate than some others. However, the question which is important to the analyst is not what is the best standard of light measurement to be eventually adopted by all as more closely conformable to the absolute theoretical standards, but what factor applies to the instruments he is using. In the majority of cases this is obviously the last. It is interesting to note that in the various works published in the last few years, all these light factors can be found, some one of them in each instance being given without comment as the correct value.

Xanthene Bases in Sugar Cane. By EDMUND C. SHOREY. *J. Am. Chem. Soc.*, **21**, 609–612.—The author finds traces of guanine in Hawaiian cane juices, and finds that this body is unchanged in the process of sugar manufacture and hence has a tendency to accumulate in the final molasses. As guanine combines with cuprous oxide, the author thinks that in the case of very low-grade products this might introduce an error if the copper is not redissolved as in the electrolytic process. He also points out that guanine may be estimated as a peptone or amide if precautions are not taken.

Report on Sugar Analysis. By R. S. HILTNER. *Proc. Assoc. Offic. Agr. Chem., Bull. U. S. Dept. Agr.*, **56**, 87–96.—The author recommends (1) that the Carr and Sanborn method for the determination of water in molasses, etc. be adopted; (2) that the quartz sand method be optional, however; (3) that the density method be restricted to high-grade products; (4) that the directions of the Lucien method for ash be revised; (5) that the Formanek be the only electrolytic method used in determining reducing sugars; (6) that in the directions for the permanganate method for reducing sugars the number of grams of permanganate used be stated; and (7) that the Creydt method for the determination of sucrose and raffinose be adopted provisionally.

INORGANIC CHEMISTRY.

HENRY FAY, REVIEWER.

On the Color of Compounds of Bromine and Iodine. By J. H. KASTLE. *Am. Chem. J.*, **21**, 398–413.—The color of the compounds of the halogens is discussed, and it is shown that the power of producing color increases from fluorine to iodine. It is shown that the compounds having the least color are most stable, while the colored compounds are usually easily decom-

posed, giving rise to colors which are similar to the color of the halogen in the free state. On heating a colored compound the intensity of the color is increased and the reverse process takes place on cooling. The author assumes that in colored compounds there is slight dissociation of the solid substance, the color being due to small quantities of the free halogen. The property of color in the halogen compounds is supposed to be an additive and not a constitutive property. Examples of a large number of inorganic and organic halogen compounds are given. Among the aromatic organic compounds it is shown that the color varies with the stability of the compound. Substitution of halogens in the benzene ring produces stable compounds, and they are usually colorless, while the side-chain substitution products are usually colored and are more unstable.

The Action of Ammonia and Amines on Chlorides of Silicon. By Felix Lengfeld. *Am. Chem. J.*, **21**, 531–537.—On bringing together benzene solutions of ammonia and silicon tetrachloride, silicon tetramide, $Si(NH_2)_4$, is formed. This substance breaks down, rapidly with water and more slowly in the air, with loss of ammonia into silicon diimide, $Si(NH)_2$. It had generally been believed that the product of the action of ammonia on silicon tetrachloride was the compound $SiCl_4.6NH_3$, but the author considers it a mixture of silicon diimide and ammonium chloride, the composition of the mixture being represented by the formula $Si(NH)_2.4NH_4Cl$. Silicon tetrethylamine is a colorless oil that does not solidify in a freezing-mixture. It keeps indefinitely in closed tubes, is decomposed by water, and boils at 102° under a pressure of 20 mm.

The Action of Chromic Acid on Hydrogen. By Chas. L. Reese. *Am. Chem. J.*, **22**, 158–164. Hydrogen is oxidized by a saturated chromic acid solution in presence of a porous material like platinized asbestos, burnt clay balls or balls made of gypsum, but pure chromic acid does not oxidize hydrogen even in the presence of considerable quantities of sulphuric acid. The oxidation of hydrogen takes place at and above 61° when heated for a sufficient length of time; but at 50° the absorption is very slight, even after two hundred and eighty-eight hours, and at 40° there is no oxidation. Saturated solutions of chromic acid evolve oxygen freely at 119° and above, and as hydrogen is oxidized at temperatures below those at which oxygen is given off, the oxidation of hydrogen seems not to be dependent upon the evolution of oxygen from chromic acid by heat. Electrolytic hydrogen produced by passing a current through a chromic acid solution, is not oxidized by pure chromic acid, but is readily oxidized in the presence of other substances. When sulphuric

acid or sulphates are added, oxidation takes place up to a certain limit, depending upon the percentage of sulphuric acid, and then ceases entirely.

Dehydration of Crystals of Sodium Phosphate. By T. C. Whitlock and C. E. Barfield. *Am. Chem. J.*, **22**, 214–215. The water of constitution of disodium hydrogen phosphate begins to be lost at 230°; below this temperature water of crystallization may be determined.

Solubility of Lead Sulphate in Ammonium Acetate. By J. C. Long. *Am. Chem. J.*, **22**, 217–218.—Approximate values of the solubility of lead sulphate in ammonium acetate solution are given.

Classifications of the Carbides: Their Modes of Formation and Reactions of Decomposition. By J. A. Mathews. *J. Am. Chem. Soc.*, **21**, 647–650.—The author has classified the carbides according to their arrangement in the periodic system, their decomposability by water, their reaction with the halogens or halogen acids, and their behavior toward heat and oxidizing agents. The different methods of preparation and the products of decomposition which serve as a means of classification, are given.

Preparation of Graphitoidal Silicon. By Frederick S. Hyde. *J. Am. Chem. Soc.*, **21**, 663–665.—The method depends upon the reduction of finely pulverized white sand with magnesium powder and the subsequent fusion of the reduction-product with cryolite and aluminium, thus forming an alloy of aluminium and silicon, from which the latter is obtained on treatment with hydrochloric acid.

Action of Hydrochloric Acid Gas upon Sulphates, Selenates, Tellurates, and Phosphates. By Raymond W. Tunnell and Edgar F. Smith. *J. Am. Chem. Soc.*, **21**, 929–932.—Hydrochloric acid completely removes selenium and tellurium from the mixture of selenic or telluric acids with phosphoric acid, but will not separate these elements from sulphuric acid, some of the latter always being carried over. It was found that dry hydrochloric acid passed over dry potassium sulphate in the cold, combined with the latter, and the product formed maintained its composition at 130° and did not lose in weight when kept over soda-lime in a vacuum desiccator for fifteen hours. When dry potassium sulphate was heated in dry hydrochloric acid gas from 200° to a dull red heat, sulphuric acid was found in the receiver, while the substance remaining behind after this treatment weighed more than the original substance.

The Precipitation of Copper by Zinc. By John C. Shengle and Edgar F. Smith. *J. Am. Chem. Soc.*, **21**, 932–933.—The precipitation of copper by zinc was found to give fair quantitative results, but some zinc was always found in the copper.

The Persulphates of Rubidium, Cesium, and Thallium. Arnott R. Foster and Edgar F. Smith. *J. Am. Chem. Soc.*, **21**, 934–936.—These salts were prepared by electrolyzing a mixture of two parts sulphuric acid (sp. gr. 1.35) with one part of a saturated solution of the sulphate. It was impossible to isolate the thallium persulphate on account of its great solubility and the rapidity with which it decomposed in the air.

BIOLOGICAL CHEMISTRY.

A. G. Woodman, Reviewer.

Saw Palmetto. By P. L. Sherman and C. H. Briggs. *Pharm. Archives*, **2**, 101–116.—The oil extracted by pressure from the fruit of the saw palmetto and also that expressed from the nuts were examined in order to ascertain their composition. The oil obtained from the pulp of the fruit was distilled under reduced pressure and found to consist of caproic, caprylic, capric, lauric, palmitic, and oleic acids and their ethyl esters, about 62 per cent. of the oil being free acids and 37 per cent. esters. The oil of the nuts contained only 2.3 per cent. free acids, the greater part of it being the glycerides of the same acids as the pulp oil with the addition of stearic acid and without the caproic acid. No alkaloids were found and the fruit was found to contain 5.4 per cent. of invert sugar.

Improvement in the Chemical Composition of the Corn Kernel. By C. G. Hopkins. *Ill. Agr. Expt. Sta., Bull.* **55**, 205–240.—Experiments have been made with the object of improving the composition of the grain. The results which have been thus far obtained indicate that it is possible to bring this about by proper selection of the seed. The proportion of protein, fat, or carbohydrate may be increased or diminished at will. The fat content of the grain seems to be more susceptible to the influence of seed selection than is the protein content.

A Chemical Study of Wheat. By G. B. Frankforter and E. P. Harding. *J. Am. Chem. Soc.*, **21**, 758–769.—The authors have studied wheat oil, determining some of the usual analytical constants. By extracting the saponified oil with ether and also by a new method involving the elaidin reaction a form of cholesterol, corresponding closely to paracholesterol, was obtained.

Egg Albumin. By Thomas B. Osborne. *J. Am. Chem. Soc.*, **21**, 477–485.—Crystallized egg albumin, prepared by the addition of hydrochloric or acetic acid and ammonium sulphate to egg white, was purified by recrystallization and dialysis and analyzed. The results obtained furnish additional evidence that egg albumin as usually prepared is a mixture of two protein substances found in egg white.

On Some Definite Compounds of Protein Bodies. By Thos. B. Osborne. *J. Am. Chem. Soc.*, **21**, 486–493.—By the use of various indicators it is shown that many of the forms of protein as usually hitherto prepared are either chemical compounds of the protein substance with ordinary mineral acids, or at least contain such compounds. This subject has been investigated more especially in the case of edestin, the mono- and bihydrochlorates of which have been prepared and studied.

The Physiological Effect of Creatin and Creatinin and Their Value as Nutrients. By J. W. Mallet. *U. S. Dept. Agr., Bull.* **66**, 1–24.—A study of the chemical and physical properties of creatin and creatinin made on considerable quantities of the pure substances showed some disagreement with the description given in text-books. Determinations of the molecular heat of combustion made by Atwater gave 559 calories for creatin and 517.9 calories for creatinin. Before carrying out the physiological experiments a method was worked out and used for the quantitative separation of creatin, creatinin, and urea, which gave fairly good results. In the physiological experiments the rates of the pulse and the respiration, the body temperature, and the reaction of the urine were observed at definite intervals. The amounts of creatin, creatinin, and urea in the excreted urine were determined. The principal conclusion derived from the results obtained is that the flesh bases do not undergo metabolism in the body, but are for the most part eliminated by way of the kidneys. Creatinin is excreted unchanged, while creatin is very largely converted to creatinin. Creatin and creatinin, then, although occurring in food, are to be disregarded as sources of energy, being eliminated from the body practically unchanged.

The Toxic Action of Sodium Fluoride. By Herbert B. Baldwin. *J. Am. Chem. Soc.*, **21**, 517–521.—The author mentions several recent cases of ill effects resulting from the use of sodium fluoride and cites the work of a number of investigators, which goes to show that sodium fluoride belongs to the class of the less violent poisons.

Food Products. By A. L. Winton and Others. *Conn. Agr. Expt. Sta., Ann. Rep.* **22**, *Part II*, 106–223.—This is a report of

the results obtained in the analysis of various food products offered for sale throughout the state, with a description of the analytical methods employed.

The Chemical Composition of American Food Materials. By W. O. Atwater and A. P. Bryant. *U. S. Dept. Agr., Bull.* **28** (Rev. Ed.), 1–87.—This bulletin contains the maximum, minimum, and average analyses of all available American food products up to Jan. 1, 1899, with the exception of milk, butter, and other dairy products, and of sugars. The literature of the subject has been thoroughly gone over, and the tables of analyses will be found quite complete.

Some Nevada Soils. By N. E. Wilson. *Nev. Agr. Expt. Sta., Bull.* **39**, 1–30.—This bulletin contains the results of analyses of twenty-six samples of representative Nevada soils.

Notes on Alkali Soil in Montana. By F. W. Traphagen and W. M. Cobleigh. *J. Am. Chem. Soc.*, **21**, 753–757.—The alkali found in the Montana soils consists almost entirely of sulphates, mainly sodium sulphate. This alkali is ordinarily concentrated in a zone at a considerable depth, but when irrigation is employed the salts begin to rise to the surface and cause damage to the crops. When, however, the soil is underlain with gravel the alkali does not rise, showing that the best remedy consists in underdrainage.

Commercial Fertilizers. *Vt. Agr. Expt. Sta., Bull.* **69**, 41–53; **70**, 55–68; **71**, 71–116; *Tex. Agr. Expt. Sta., Bull.* **51**, 24–37; *R. I. Agr. Expt. Sta., Bull.* **56**, 1-9; *Ky. Agr. Expt. Sta., Bull.* **82**, 15-32.

G. W. Rolfe, Reviewer.

The Sugar Beet in Maryland. By H. W. Wiley. *Md. Agr. Expt. Sta., Bull.* **61**, 169–186.—The author reviews the history of the experimental work done in the state, and concludes that "in the present state of the sugar industry it has been established that Maryland cannot successfully compete in the manufacture of beet-sugar with more favorable localities in the United States."

Sugar as Food. By Mary Hinman Abel. *Farmers' Bull. U. S. Dept. Agr.*, **93**, 7–26.—This bulletin treats in a popular way of the composition, sources, food value, and practical use of cane-sugar.

Variations in the Analyses of Cane Ashes. By Robt. Hall. *La. Planter*, **23**, 179–180.—The extraordinary variations in the

amount of fertilizing constituents, especially potash, shown by published analyses, are pointed out.

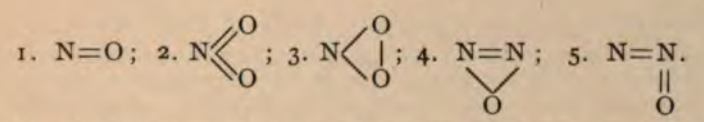
The Field of Chemical Improvement in the Manufacture of Cane Sugar. By WILFRED SKAIFE. *La. Planter*, **23**, 107–109.—The author reviews some of the great problems of sugar manufacture from field to finished product.

ORGANIC CHEMISTRY.

J. F. NORRIS, REVIEWER.

Trinitrophenylmalonic Ester. By C. LORING JACKSON AND J. I. PHINNEY. *Am. Chem. J.*, **21**, 418–433.—Trinitrophenylmalonic ester, as prepared by Jackson and Soch (*this Rev.*, **2**, 10), crystallizes from alcohol in slender, rectangular needles, which melt at 58°. When precipitated from its ammonium salt and recrystallized the ester is obtained in kite-shaped crystals, which melt at 64°. The low-melting crystals are readily changed into the high-melting variety by melting, and by inoculating a saturated solution of them with a crystal of the form melting at 64°. After the high-melting crystals were once obtained it was found difficult to prepare the unstable form, as the dust of the former in the laboratory influenced the crystallization of the compound. It was found impossible to convert the stable into the unstable form. The two compounds were not polymeric modifications, as the new body was shown to have a simple molecular weight. Alkalies give with the ester melting at 64° dark-red salts, which crystallize well. The barium, strontium, calcium, zinc, cadmium, copper, and lead salts are highly-colored precipitates. When the ester was treated with concentrated nitric acid on the steam-bath, a nitrite was formed of the formula $C_6H_2(NO_2)_3CONO(CO_2C_2H_5)_2$ (m. p. 109°). By long-continued action of nitric acid, trinitrophenyltartronic ester (m. p. 167°) results, which is converted into an acetyl derivative (m. p. 125°) when heated in a sealed tube with acetyl chloride. Trinitrophenylacetic acid (m. p. 161°) was formed when the trinitrophenylmalonic ester (m. p. 64°) was saponified with sulphuric acid.

The Relation of Trivalent to Pentavalent Nitrogen. By ARTHUR LACHMAN. *Am. Chem. J.*, **21**, 433–446.—In order to get some experimental evidence for the structure of nitro and azoxy compounds, a number of substances containing these groups, as well as nitroso compounds, were subjected to the action of zinc ethyl. The structures usually assigned to these groups are as follows:



If nitro and azoxy groups have the structure of formulæ 2 and 5, respectively, compounds containing them should show some resemblance to nitroso compounds (formula 1); whereas if formulæ 3 and 4 are correct this similarity should be lacking. Diethylnitrosamine and phenylmethylnitrosamine do not react with zinc ethyl. Diphenylnitrosamine, however, which contains two aromatic groups, reacts with violence. The resulting product, which contains the amine and zinc alkyl in equal molecular quantities, decomposes with water and diphenylamine, $\beta\beta$-diethylhydroxylamine, and zinc hydroxide are formed. It is seen, therefore, that the reactive power of the nitroso group is determined by the nature of the groups with which it is united. The reaction between zinc ethyl and nitrosobenzene is a violent one, the chief reaction-products being azoxybenzene and phenylhydroxylamine. A small amount of aniline and ethylaniline is formed, but no diethylaniline could be found. Azoxybenzene does not react with zinc ethyl after long standing; it, therefore, probably has the formula usually assigned to it (number 4). Three nitro compounds were studied. Dimethylnitramine does not react with zinc ethyl; nitroethane readily forms an addition-product, which gives trimethylamine oxide, as pointed out by Bewad, and nitrobenzene reacts but slightly, the bulk of the reaction-product being a neutral, sticky mass of disagreeable character. Taking into consideration the above facts and the general result reached with the nitroso compounds, *viz.*, that negativity and reactiveness are proportional, the conclusion is drawn that nitrobenzene and nitroethane are differently constituted, the former showing the grouping represented by formula 3 above, while the latter contains a pentavalent nitrogen.

Some Derivatives of Camphoroxime. By G. B. Frankforter and A. D. Mayo. *Am. Chem. J.*, **21**, 471–473.—Acetyl camphoroxime, $C_{10}H_{16}NO(CH_3CO)$ (b. p. 170°), is formed when camphoroxime is allowed to stand with acetic anhydride. If heat is applied the nitril $C_{10}H_8N$ results. With chloral, in ethereal solution, the reaction-product is chloral camphoroxime $(C_{10}H_{16}NO)_2CHCCl + 2H_2O$, a crystalline powder which melts at 82° and decomposes spontaneously. Succinylcamphoroxime boils with decomposition at 246° and decomposes on standing.

Camphoroxime Derivatives. By G. B. Frankforter and P. M. Glasoe. *Am. Chem. J.*, **21**, 474–478.—Phthalic anhydride reacts with camphoroxime in boiling benzene to form an ester which melts with decomposition at 135.5°. Camphorformaldoxime, $C_{10}H_{16}NO.CH_2OH + H_2O$ (m. p. 62°–63°), was prepared by boiling the oxime with an aqueous solution of formic aldehyde and treating the resulting oil with a large quantity of water for several days. If the oil obtained as above is exposed to the sunlight, a part of it is changed into camphorparaformaldoxime, $C_{10}H_{16}N(C_3H_6O_3)$. Monochlorcamphoroxime (m. p. 290°) was formed when an ethereal solution of the oxime was treated with sulphothionyl chloride.

The Composition of Nitrogen Iodide and the Action of Iodine on the Fatty Amines. By James F. Norris and Arthur I. Franklin. *Am. Chem. J.*, **21**, 499–510.—Iodine readily reacts with triethylamine. In ethereal solution triethylamine hydroiodide and the periodide, $(CH_3)_3N.HI.I_2$, are formed; in aqueous solution iodoform is one of the products of the reaction. Tripropylamine forms an addition-product of the formula $(C_3H_7)_3N.I_2$ (m. p. 66°), analogous to the trimethylamine compound already described, and a periodide containing three iodine atoms. With diethyl, diamyl, and methylamine the products were periodides and hydroiodides. From the above facts the conclusion is drawn that iodine readily attacks the amines, causing substitution, and that this is accompanied by the formation of an addition-product of iodine and the amine only in the case of tertiary amines. This conclusion is inconsistent with the formula of nitrogen iodide, $NH_3.I_2$, recently put forward by Chattaway (*J. Chem. Soc.*, **69**, 1572). A number of the arguments adduced in favor of the above formula are answered. The compound prepared by Guthrie (*J. Chem. Soc.*, **1**, 239) and by Seamon (*Chem. News*, **44**, 188), and to which the formula $NH_3.I_2$ was assigned, is probably a mixture of nitrogen iodide and ammonium periodide. This was shown by studying, side by side, the solubility in a number of solvents of such a mixture and the substance prepared as directed by the above authors.

On the Action of Sodic Ethylate on Tribromdinitrobenzol. By C. Loring Jackson and Waldemar Koch. *Am. Chem. J.*, **21**, 510–528.—The constitution of the dinitroresorcinediethyl ether melting at 133°, formed by the action of a hot solution of sodium ethylate on tribromdinitrobenzene ($Br_3$1,3,5,$(NO_2)_2$2,4), or on the bromdinitroresorcinediethyl ether melting at 184°, was determined by saponifying the ether to the corresponding dinitroresorcine, which proved to be the symmetrical compound

$(OH)_2 1,5,(NO_2)_2,2,4$. It follows that the bromine replaced by hydrogen in tribromdinitrobenzene is the one between the two nitro groups, and that the bromdinitroresorcinediethyl ether melting at 184° has the constitution $(OC_2H_5)_2 1,5,Br3,(NO_2)_2 2,4$. An isomeric ether, in which the bromine is not in the ortho position to two nitro groups, gave no replacement of the atom of bromine by hydrogen when treated with sodium ethylate, but gave dinitrophloroglucinetriethyl ether by the replacement of the bromine by an ethoxy group. As a result of the action of sodium ethylate on tribromdinitrobenzene (m. p. 192°) at ordinary temperature in benzene or alcohol solution, the following substances were formed: Two bromdinitroresorcinediethyl ethers, $(OC_2H_5)_2 1,5,Br3,(NO_2)_2 2,4$ (m. p. 184°), and $(OC_2H_5)_2 1,3,Br5(NO_2)_2 2,4$ (m. p. 92), tribromnitrophenol, $Br_2 1,3,5,NO_2 2,OH4$ (m. p. 90°), dinitroresorcineethyl ether, $(OC_2H_5)1,OH5,(NO_2)_2 2,4$ (m. p. 77°), and dinitrophloroglucinetriethyl ethers, $(OC_2H_5)_2 1,3,5,(NO_2)_2 2,4$. The most striking phenomenon in the action of sodium ethylate on tribromdinitrobenzene at 70° is the replacement by hydrogen of the atom of bromine in the ortho position to both nitro groups, a reaction that takes place to but a slight extent in the cold. The absence of dinitrophloroglucinetriethyl ether when the reaction takes place at 70° is also noteworthy. The mechanism of all the reactions mentioned is explained at length but the discussion cannot be briefly abstracted.

The Action of Sulphocarbanilide on Certain Acid Anhydrides. By Frederick L. Dunlap. *Am. Chem. J.*, **21**, 528–531.—When equal molecular quantities of sulphocarbanilide and maleïc anhydride were intimately mixed and heated to 80°–95°, diphenylthiomaleïnuric acid,

$$HOOCCH : CHCONC_6H_5CSNHC_6H_5,$$

(m. p. 160°) was formed by the direct addition of the two reacting substances. The acid forms crystalline barium, calcium, silver, potassium, and sodium salts. With succinic and phthalic anhydrides no addition-product could be isolated, however. Succinanilic acid, the product of the reaction with the corresponding anhydride, crystallizes from water in prisms which melt at 144.5°–145.5°.

Optical Rotation of Pinen Hydrochloride. By J. H. Long. *J. Am. Chem. Soc.*, **21**, 637–642.—It is shown that the effect of temperature on the preparation of pinen hydrochloride from turpentine is unimportant, since the compound prepared below 0° had the same specific rotation as that prepared at 40°. The author holds that turpentine obtained from one tree contains both

d- and *l*-pinen, and that the different values of the optical rotation of pinen hydrochloride, obtained by different observers, are due to the varying proportions of the two varieties in the oils investigated. It is also shown that the separation of *d*- and *l*-pinen cannot be effected by the fractionation of the compounds themselves or their hydrochlorides. The rotation of the hydrochloride prepared from *l*-pinen is greater than that of *l*-pinen, whereas the rotation of the hydrochloride of *d*-pinen is probably somewhat less than that of *d*-pinen. It follows, therefore, that when a *d*-pinen containing some *l*-pinen is treated with hydrochloric acid the rotation of the resulting compound may be reduced to zero. These facts explain the statement of Wallach and Conrady that *d*-pinen is rendered inactive by hydrochloric acid.

Camphoric Acid (Sixth Paper). By WILLIAM A. NOYES. *Am. Chem. J.*, **22**, 1–5.—The incorrectness of Collie's formula for camphoric acid was established by showing that cis campholytic acid (isolauronolic acid) and Δ^1-tetrahydroxylic acid, $C_6H_6.CH_3(1).COOH(2).CH_3(3)$, are not identical. The neighboring xylic acid was reduced with sodium and amyl alcohol and the corresponding hexahydroxylic acid (m. p. 72°, b. p. 250°–252°) obtained to the extent of about 50 per cent. of the theoretical yield. By treating the reduced acid with phosphorus pentachloride and bromine the chloride of α-bromhexahydroxylic acid, $C_6H_8.CH_3(1).Br.COOH(2).CH_3(3)$, was obtained. This compound is quite stable toward water, is not readily effected by dilute sodium hydroxide, but is decomposed when warmed with glacial formic acid, from which the acid crystallizes in leaflets which melt at 150°–151°. When the α-brom acid is warmed with alcoholic potassium hydroxide, Δ^1-tetrahydroxylic acid is formed, which melts at 89°–90° after crystallization from ligroin. This acid differs from other acids of similar structure in that it is not readily oxidized by potassium permanganate.

On Undecylamine and Pentadecylamine and the Preparation of the Higher Amines of the Aliphatic Series. By ELIZABETH JEFFREYS. *Am. Chem. J.*, **22**, 14–45.—Some time ago Lengfeld and Stieglitz (*Am. Chem. J.*, **16**, 270) showed that sodium methylate in methyl alcohol solution converts acid bromamides into urethanes according to the reaction

$$RCONHBr + CH_3ONa = RNHCOOCH_3 + NaBr.$$

The author shows that the resulting urethanes are converted quantitatively into amines when distilled with slaked lime, and that the reaction serves as an excellent method of preparing the higher aliphatic amines, which are obtained with difficulty by

the older methods. The process is a simple one, since the urethanes are obtained without the isolation of the brom- or chloramides by the action of a sodium alcoholate on a mixture of the acid amide and bromine. The method is applicable to the preparation of both aliphatic and aromatic urethanes, in ethyl and methyl alcohol solution, but cannot be used when the acid amide is unsaturated or otherwise very susceptible to bromine. The amines obtained by this method were shown to be primary monoalkyl amines by the preparation of a mustard oil and an isocyanate from pentadecylamine, and by the formation of primary alcohols when sodium nitrite was allowed to act upon the amine hydrochlorides. In the preparation of the higher amines by the Hofmann reaction acyl alkyl ureas are formed to a large extent. This is shown to take place whenever, owing to the slowness of the reaction, considerable unchanged acid amide is present, while the remainder of the acid amide is suffering rearrangement; the rearranged portion then reacts with the unchanged amide even in the presence of alcohol or water and forms a urea. This is remarkable, inasmuch as isocyanates, the probable intermediate products in the Beckmann rearrangement, under ordinary circumstances do not act upon an acid amide in the presence of alcohol or water. Palmitic chloramide (m. p. 70°–71°), prepared by the action of sodium hypochlorite on palmitic amide, was obtained as a white precipitate and converted by sodium methylate into methyl pentadecylurethane which crystallizes in leaflets melting at 61°–62°. This compound, as well as methyl phenylcarbamate and methyl *m*-nitrophenylcarbamate were prepared from the amides directly by the action of a mixture of bromine and sodium methylate. Normal pentadecylamine hydrochloride, prepared from the free amine (obtained by distilling pentadecylurea with lime), crystallizes in leaflets which decompose at 200° without melting. The chlorplatinate decomposes at 205°. The corresponding urea (m. p. 109°) was prepared from the hydrochloride and potassium cyanate. Pentadecylamine crystallizes in leaflets, melts at 36.5°, boils at 298°–301°, and rapidly absorbs carbon dioxide and water. Its benzoyl derivative melts at 78°. The amine was shown to be a primary one by the action of carbon disulphide, phosgene, and sodium nitrite. In ether solution carbon disulphide gave pentadecylamine pentadecyldithiocarbamate (m. p. 99°) which, when heated in a sealed tube, was converted into dipentadecylthiourea (m. p. 88.5°). Pentadecyl mustard oil was prepared in impure condition by heating pentadecylamine, in solution in absolute alcohol, with an excess of carbon disulphide. The mustard oil was identified by treating it with aniline, when phenylpentadecylthiourea (m. p. 79°) was obtained. By the action of phos-

gene on the amine hydrochloride pentadecylurea chloride, $C_{15}H_{31}NHCOCl$, was obtained. The compound is unusually stable for substances of this class; it can be heated for several hours at 100°–150° without losing all of its hydrogen chloride. Pentadecylisocyanate (m. p. 8°–14°) was prepared by dissolving the urea chloride in benzene and heating it with calcium oxide. Dipentadecylurea (m. p. 113°) was obtained by heating the isocyanate with pentadecylamine. With sodium nitrite pentadecylamine hydrochloride gave a mixture of the corresponding alcohol and the hydrocarbon $C_{15}H_{30}$. Pentadecylphenylcarbamate (m. p. 72°) was formed when the alcohol and phenyl isocyanate were allowed to stand together. In order to find whether the methods described for obtaining urethanes and amines are general for amides of high molecular weight, the same reactions were carried out with stearic and lauric amides. The preparation of the following compounds showed that the reactions are general: Stearic chloramide (m. p. 63°–64°), methyl heptadecylcarbamate, heptadecylamine, methyl undecylcarbamate (m. p. 45°–47°), undecyllaurylurea (m. p. 105°), undecylamine hydrochloride, undecylamine chlorplatinate decomposing at 190°, normal undecylamine (m. p. 15°, b. p. 232°), benzoylundecylamine (m. p. 60°), normal undecyl alcohol (m. p. 19°, b. p. 131° at 15 mm.), undecylphenylcarbamate (m. p. 62°), undecylene (b. p. 84° at 18 mm.), and undecylene dibromide (b. p. 161° at 18 mm.).

On Certain Derivatives of Symmetrical Trichlorbenzol. By C. Loring Jackson and F. H. Gazzolo. *Am. Chem. J.*, **22**, 50–61.—In a previous paper Jackson and Calvert (*this Rev.*, **2**, 76) showed that when tribromiodobenzene, $Br_3 1,3,5,I2$, and tetrabrombenzene, $Br_4 1,2,3,5$, were treated with sodium ethylate, the halogen in position 2 was replaced by hydrogen. The investigation of the corresponding trichlor derivatives has now been made. Trichloriodobenzene, $Cl_3 1,3,5,I2$ (m. p. 55°) and sodium ethylate gave symmetrical trichlorbenzene. With fuming nitric acid trichlordinitrobenzene (m. p. 129°) was formed, iodine being set free. Trichlorbrombenzene, $Cl_3 1,3,5,Br2$, melts at 65°, loses bromine with sodium ethylate, and with fuming nitric acid gives trichlorbromdinitrobenzene, melting at 175°, which is a decidedly reactive substance. Aniline replaced three atoms of chlorine, giving trianilidobromdinitrobenzene melting at 175°–176°. With sodium ethylate a number of compounds are formed, from which bromdinitroresorcinediethyl ether (m. p. 81°–82°), having the probable structure $(C_2H_5O)_2 1,3, Br2(NO_2)_2 4,6$, was separated in pure condition. The formation of this compound is interesting in that it is the first case noted

in which chlorine has been replaced by hydrogen under these conditions.

Narcotine and Narceine. By George Bell Frankforter and Frank H. Keller. *Am. Chem. J.*, **22**, 61-67.—The authors doubled the yield of narceine obtained from narcotine-methyl iodide by converting the latter into the chloride by means of chlorine water instead of silver chloride. The secondary product obtained when the old method is used is probably the compound $C_7H_6(CH_3)_2N_3Cl.2AgI$. When chlorine water is used the by-product of the reaction is narcotine-methyl triiodide $C_{22}H_{27}I_2NO_7CH_3I$ (m. p. 149°). When this compound is treated with an excess of chlorine water, methylnornarcotine-methyl triiodide, $C_{20}H_{27}I_2NO_7.CH_3I$ (m. p. 186°), is formed. Narcotine methyl chloride forms a double salt with platinic chloride, which melts at 221°.

The Reaction between Aliphatic Sulphocyanates and Metallic Derivatives of Acetoacetic Ester and Analogous Substances. By Elmer P. Kohler. *Am. Chem. J.*, **22**, 67-80.—The primary reaction between the metallic derivatives of the esters of ketonic acids and aliphatic sulphocyanates results in the formation of a mercaptide and a cyanogen substitution-product of the ester. The final result depends, to some extent, upon the ester, the metal, and the sulphocyanate. If the resulting mercaptide is soluble in the liquid used as a medium, it immediately reacts with the unchanged sulphocyanate to form a disulphide. A typical reaction is represented by the following equation:

$$CH_3COCNaC_2H_5COOC_2H_5 + 2C_2H_5SCN = CH_3COC(CN)C_2H_5COOC_2H_5 + (C_2H_5S)_2 + NaCN.$$

In case the cyanogen derivative formed contains hydrogen that is replaceable by metal, it passes into a metallic derivative by liberating a corresponding amount of the original ester. With sodium derivatives, the sodium mercaptides formed slowly saponify the original esters and the cyanogen derivatives resulting from the reaction. With copper derivatives the reactions are clean, as the copper mercaptides are insoluble in organic liquids and inert. The following equation represents a typical reaction:

$$4(CH_3COCHCO_2C_2H_5)_2Cu + 4C_2H_5SCN = 2(CH_3COC(CN)CO_2C_2H_5)_2Cu + 4CH_3COCH_2CO_2C_2H_5 + (C_2H_5S)_2 + 2C_2H_5SCu.$$

The reaction between copper derivatives and polysulphocyanates that have but one sulphocyanogen group with any one carbon atom, normally involves only one of the sulphocyanogen

groups; the remainder are protected by the insolubility of the resulting mercaptide. Ethylene sulphocyanate and copper acetoacetic ester, for example, in the cold, react according to the equations:

$$\text{I.}\ (CH_3COCHCO_2C_2H_5)_2Cu + 2(CH_2SCN)_2 = 2CH_3COCH(CN)CO_2C_2H_5 + \left(\begin{array}{c} CH_2SCN \\ | \\ CH_2S \end{array}\right)_2 Cu.$$

$$\text{II.}\ \left(\begin{array}{c} CH_2SCN \\ | \\ CH_2S \end{array}\right)_2 Cu = 2\begin{array}{c} CH_2SCN \\ | \\ CH_2SCu \end{array} + \begin{array}{c} CH_2SCN \\ | \\ CH_2 \end{array}\!\!-S-S-\!\!\begin{array}{c} CH_2SCN \\ | \\ CH_2 \end{array}.$$

The sulphocyandisulphides thus formed are soluble in organic solvents and at higher temperatures react like simpler polysulphocyanates. By adding the sulphocyanate, in very small quantities, to a saturated solution of the copper derivatives, all of the sulphocyanogen groups can be brought into reaction. When polysulphocyanates have two sulphocyanogen groups in combination with the same carbon atom, both of them enter into reaction under all conditions. A difference in behavior with copper and sodium derivatives is observed in the case of halogen substitution-products of the sulphocyanates. With the former chlorethylsulphocyanate reacts, the halogen not taking part in the reaction. With the latter, two reactions take place simultaneously—the normal reaction of the sulphocyanates and the general reaction of halogen substitution-products. Copper cyanacetoacetic ester crystallizes from alcohol in green plates, which melt with decomposition at about 250°. The compound of the formula $CuSCH_2.CH_2SCN$, formed by the action of ethylene sulphocyanate on copper acetoacetic ester, when boiled with concentrated hydrochloric acid, gives iminomethene-ethenedisulphide hydrochloride,

$$\begin{array}{c} CH_2S \\ | \\ CH_2S \end{array}\!\!\!>CNH.HCl.$$

The compound represented by the formula $(NCSCH_2.CH_2S)_2$ is a colorless liquid which does not solidify at —20° and does not boil without decomposition. When warmed with strong potassium hydroxide it is converted into ethylenetetrasulphide. The mercaptide $CuSCH_2.S.CH_2SCu$ is a light yellow impalpable powder. Cyanethylacetoacetic ester boils at 130° at 35 mm. pressure, and sulphocyanethylacetoacetic ester,

$$CH_3COC(CH_2CH_2SCN)CHCO_2C_2H_5,$$

crystallizes in colorless, transparent plates, which melt at 83°.

On Nitromalonic Aldehyde. By Henry B. Hill and Joseph Torrey, Jr. *Am. Chem. J.*, **22**, 89–110.—When mucobromic acid is added to a solution of sodium nitrite in dilute alcohol a vigorous reaction takes place with rise in temperature, evolution of carbon dioxide, and change in color of the solution to a deep red. From the cooled reaction-mixture sodium nitromalonic aldehyde, $NaC_3H_2NO_4.H_2O$, crystallizes in needles. The free aldehyde (m. p. 50°–51°) was obtained by treating its silver salt suspended in ether with an ethereal solution of hydrogen chloride. The constitution of the compound was established by the reactions and condensations of the aldehyde described below. When aniline hydrochloride was added to an aqueous solution of the sodium salt of the aldehyde, an anil was formed in which an oxygen of the aldehyde groups had been replaced by the radical $=N.C_6H_5$. The compound crystallizes in yellow scales, which melt at 143°–144°. If aniline is used the dianil (m. p. 93°–94°) results. Analogous compounds were prepared with *p*-toluidine, *o*-toluidine, methylamine, ethylamine, isoamylamine, and phenylhydrazine. The phenylhydrazone melts at 101°, and is converted by heating in alcoholic solution at its melting-point into 1-phenyl-4-nitropyrazol, melting at 126°–127°. The latter compound was also obtained where the diphenylhydrazone (m. p. 98°) was heated. The diphenylhydrazone yields stable sodium and lead salts. Hydrazine sulphate and an aqueous solution of sodium nitromalonic aldehyde produced a dark red precipitate which, when decomposed with hydrochloric acid, gave as one of the decomposition-products 4-nitropyrazol. The constitution of the phenylnitropyrazol mentioned above was thus established. In neutral solution hydroxylamine hydrochloride and sodium nitromalonic aldehyde give β-nitroisoxazol (m. p. 46°–47°), in alkaline solution two molecules of the hydroxylamine enter into the reaction and the sodium salt of a dioxime is formed. This sodium salt is readily converted into a silver salt, and when treated with aniline hydrochloride is changed into nitromalonic aldehyde aniloxime (m. p. 162°). Sodium nitromalonic aldehyde condenses with acetone in alkaline solution and forms a compound which yields *p*-nitrophenol. The aldehyde condenses also with methyl-ethyl ketone, giving nitro-*o*-cresol, with benzyl ketone, giving a nitrophenol derived from *m*-diphenyl benzene, with acetoacetic ester, giving nitrosalicylic acid, and with acetone dicarboxylic acid giving nitrooxyisophthalic acid. When a solution of the sodium salt of nitromalonic aldehyde was acidified with one molecular quantity of hydrochloric acid and allowed to stand some time, symmetrical trinitrobenzene crystallized out, and formic acid appeared in the solution. It seems probable that the trinitrobenzene is formed by the spontaneous condensation of nitroacetaldehyde, which is

first formed together with formic acid by the addition of water to the nitromalonic aldehyde.

On the Rearrangement of the Thioncarbamic Esters. By H. L. Wheeler and Bayard Barnes. *Am. Chem. J.*, **22**, 141–152.—When a thioncarbamic ester, $H_2N.CS.OR$, is treated with an alkyl halide, it is converted into a thiolcarbamic ester, $H_2N.CO.SR$. This rearrangement is the result of the addition of the halide to the thion compound, either at the double bond or to the sulphur atom, and the subsequent elimination of the halogen atom with the alkyl group originally present in the thion ester. In this way methyl and ethyl thioncarbamate were changed into methyl thiolcarbamate when allowed to stand with methyl iodide. This rearrangement was shown to be a general reaction by preparing from the corresponding thioncarbamates the following thiolcarbamates: methyl (m. p. 107°–108°), ethyl (m. p. 107°–108°), isobutyl (m. p. 102°–103°), and isoamyl (m. p. 112°–113°). The isopropyl derivative (m. p. 125°) was made from the isoamyl compound. When ethyl thioncarbamate was treated with ethylene bromide both bromine atoms took part in the reaction, the ethylene ester of thiolcarbamic acid being formed. Since the alkyl halides readily change thion into thiol compounds the arguments put forward for the structure of some thiol acids, based on the action of ethyl bromide on their salts, no longer hold. The salt formed by the action of carbon oxysulphide on ammonia is probably a thion compound and not a thiol derivative, although it gives with ethyl bromide ethyl thiolcarbamate. The work suggested that a rearrangement might be effected in the case of tetravalent sulphur compounds by alkyl halides. This was found not to be the case with the esters of sulphinic acids and with alkyl sulphites.

Dimethyldianthracene: A Polymeric Modification of β-Methylanthracene. By W. R. Orndorff and H. A. Megraw. *Am. Chem. J.*, **22**, 152–157.—In a previous paper (*this Rev.*, **2**, 77) it was shown that anthracene and anthranol, when suspended in benzene and exposed to sunlight, were rapidly polymerized to compounds which had twice the molecular weight of the original substances. Under the same conditions, from β-methylanthracene a white crystalline substance is formed, which melts with slight decomposition at 228°–230° after several recrystallizations from toluene. The compound has the same percentage composition as β-methylanthracene but twice its molecular weight. It is therefore, dimethyldianthracene. The new hydrocarbon does not show the fluorescence characteristic of anthracene and methyl anthracene, and does not form an addition-compound with picric acid. It probably crystallizes in

the orthorhombic system and is changed into β-methylanthracene at its melting-point.

Action of Sulphuric Acid on Nitroheptane. By R. A. Worstall. *Am. Chem. J.*, **22**, 164–167.—When nitroheptane was treated with dilute or concentrated sulphuric acid the products of the reaction were heptoic acid and ammonia. When, however, fuming sulphuric acid was used a small amount of nitroheptane sulphonic acid was also formed. The acid which could not be purified was separated by means of its barium salt, which crystallizes in small reddish-yellow plates. An attempt was made to prepare a sulphonic acid by acting upon bromnitroheptane with sodium sulphite, but without success.

On Alkyl Malonic Nitriles and Their Derivatives. By John C. Hessler. *Am. Chem. J.*, **22**, 169–198.—The author describes in detail the preparation and reactions of a number of alkyl malonic nitriles and their derivatives. When sodium cyanacetic ester was treated with ethyl iodide in alcoholic solution, the yield of ethyl cyanacetic ester was 74 per cent. of the theoretical, and about one-fourth of the reaction-product was diethylcyanacetic ester. When no solvent was used the yield of the disubstitution-product was decreased about one-half. Ethylcyanacetamide (m. p. 113°, b. p. 180°–190° at 24 mm.) and diethylcyanacetamide (m. p. 122°) were prepared from the corresponding esters. Ethylcyanacetic acid is a hygroscopic liquid, which boils at 160°–161° at 24 mm. and forms a white crystalline silver salt. By treating dry sodium cyanacetic ester with ethyl iodide a much larger yield of benzylcyanacetic ester (b. p. 176°-185° at 21 mm.) is obtained than when alcohol is used as solvent. Dibenzylcyanacetic ester, which is obtained at the same time, melts at 33°. From analogy with other compounds of the same class the sodium salt of cyanacetic ester has probably the constitution represented by the following formula:

$$CN{-}CH{=}C\begin{cases} ONa \\ OC_2H_5 \end{cases}.$$

Benzylcyanacetamide (m. p. 130°) is converted into benzylmalonic nitrile (m. p. 91°) by phosphorus pentachloride. When the sodium salt of the nitrile was heated under diminished pressure hydrocinnamic nitrile was formed. The formation of an inorganic cyanide, when the sodium and silver salts of the nitrile are heated, is evidence for the following formula for the salts: $C_6H_5CH_2(CN)C{=}C{=}N.M$. The sodium and silver salts of ethylmalonic nitrile (b. p. 200°) behave in the same way when heated, but it was found impossible to separate in pure condi-

tion any organic substance formed in the decomposition. When malonic nitrile was heated with alcoholic sodium ethylate and benzyl chloride the resulting mixture of the mono- and dibenzyl substitution-products contained 90 per cent. of the latter compound. When the dry sodium salt of the nitrile was used the yield of the mono derivative was increased. Benzylcyanacetic acid melts at 101°–102° and gives a white insoluble silver salt. Benzoylbenzyl nitrile melts at 100° and is converted into benzylmalonic nitrile and ethyl benzoate when boiled with alcohol. Brombenzylmalonic nitrile (m. p. 119°–120°) was prepared by brominating sodium benzylmalonic nitrile. From the sodium salt carbethoxybenzylmalonic nitrile (m. p. 44°–45°) was prepared by the action of chlorcarbonic ether, and methylbenzylmalonic nitrile (m. p. 94°–95°) by the action of methyl iodide. By the action of methyl iodide and alcoholic sodium ethylate on benzylmalonic nitrile, methylbenzylcyanacetimidoethyl ester (b. p. 170° at 22 mm.) was formed and not the nitrile, which is usually formed by this reaction. The corresponding ethyl derivative (b. p. 170° at 22 mm.) was prepared from benzylmalonic nitrile and ethyl iodide, and from ethylmalonic nitrile and benzyl chloride. Phenylacetamidoethyl ester, prepared from the chloride by the method of Bushong, boils at 105°–106° at 10 mm. Monimidomalonic ester, made from cyanacetic ester by the method of Pinner, decomposes when heated to 165° at ordinary pressure.

On the Phenylhydrazones of Benzoin. By Alexander Smith. *Am. Chem. J.*, **22**, 198–207.—Some time ago Smith and Ransom (*Am. Chem. J.*, **16**, 108) described the preparation and properties of a substance formed by the interaction of phenylhydrazine and benzoin, which differed in physical properties, although not in chemical properties and composition, from the phenylhydrazone which was known at that time. The relation between these two bodies has been recently investigated by Freer (*this Rev.*, **5**, 32) who obtained results not in accord with those obtained by Smith and Ransom. Freer found that the bodies behave differently towards benzoyl chloride and nitrous anhydride, and from these facts came to the conclusion that the compounds are not stereoisomers, but are structurally different, one being a hydrazo derivative and the other a hydrazone. The author has repeated the work of Smith and Ransom and finds nothing to modify in their published statements. It is also shown that the substance described by Freer as γ-phenylhydrazone is benzanilide, and that the two phenylhydrazones of benzoin show the same behavior when treated with benzoyl chloride and with nitrous anhydride. There is no evidence, therefore, against the stereochemical explanation of the isomerism of the hydrazones.

Disulphones and Ketosulphones. By Elmer P. Kohler and Margaret B. MacDonald. *Am. Chem. J.*, **22**, 219–227. —The sodium salts of sulphinic acids react readily with acid chlorides, giving substances of a new class: with sulphone chlorides, disulphones $RSO_2—SO_2R$, and with the chlorides of the carbonic acids, ketosulphones $RCO—SO_2R$ are formed. The disulphones are remarkably inert; they are not changed by boiling with dilute acids or alkalies and can be crystallized without loss from concentrated nitric acid. They are broken down, however, when boiled with concentrated potassium hydroxide into a sulphinate and a sulphonate. Di-*p*-tolyldisulphone is insoluble in water and alcohol and crystallizes from benzene in monoclinic tables, which melt with decomposition at 212°. Phenyl-*p*-tolyldisulphone (m. p. 166°) and *p*-tolyl-*p*-nitro-*o*-tolyldisulphone (m. p. 154°) were also prepared and studied. Phenyl-*p*-tolylketosulphone, $C_6H_5CO—SO_2C_6H_4.CH_3$, formed by the action of benzoyl chloride on sodium toluenesulphinate, was found to be a very reactive substance, which formed addition-products with water, hydrogen potassium sulphite, and hydrocyanic acid, and showed the usual ketone reactions with hydroxylamine, phenylhydrazine, primary amines, and phenols. The hydrate of the compound melts at 80° and decomposes before the water is driven off.

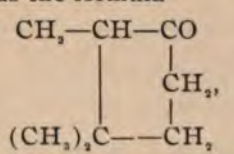
The Reaction between Sulphone Chlorides and Metallic Derivatives of Ketonic Esters. By Elmer P. Kohler and Margaret B. MacDonald. *Am. Chem. J.*, **22**, 227–239.—The reaction between toluene sulphone chloride and the sodium derivative of acetoacetic ester is much more complicated than the analogous reaction with the chlorides of the carbonic acids. With the sulphone chloride the primary reaction consists in the interchange of sodium and chlorine with the formation of sodium toluenesulphinate and chloracetoacetic ester. The latter compound then reacts with some of the unchanged sodium derivative to form diacetosuccinic ester and sodium chloride. The chlor ester also reacts with the sodium toluenesulphinate forming toluenesulphoneacetoacetic ester, which in turn reacts with the alcohol present and forms toluenesulphonacetic ester. Although it was found impossible to isolate toluenesulphoneacetoacetic ester, its sodium derivative was prepared in small quantity as the result of a secondary reaction between the sodium derivative of acetoacetic ester and the ethyl ester of toluenethiosulphonic acid, the primary reaction being the formation of sodium toluenesulphinate, diacetosuccinic ester, and ethyl disulphide. The products of the reaction between toluenesulphone chloride and sodium malonic ester were sodium toluenesulphinate and sodium toluenesulphoneacetic acid. With disodium malonic

ester, a salt of the composition $C_7H_7SO_2CNa.CO_2Na.CO_2C_2H_5$ was formed, which was decomposed into toluenesulphonacetic ester by hydrochloric acid. The course of the reaction between sodium toluenesulphinate and chloracetoacetic ester was found to depend upon the temperature and concentration. In cold dilute solutions an acetyl or carbethoxyl group is replaced by the sulphone group; in boiling concentrated solutions the sulphinate is oxidized and the chlor ester reduced.

On Potassium Cyanide as a Condensing Agent. By Alexander Smith. *Am. Chem. J.*, **22**, 249–256.—Condensation of benzoin with ketones is readily effected by means of potassium cyanide. The reaction takes place in alcoholic solution, but a better yield is obtained when the substances are fused with the cyanide. Desyl-α-acetonaphthone, $\begin{array}{c} C_6H_5.CH.CH_3 \\ | \quad\quad | \\ C_6H_5.CO \quad COC_{10}H_7 \end{array}$, prepared from benzoin and α-acetonaphthone melts at 151°. When treated with cold concentrated sulphuric acid it is converted into diphenyl-α-naphthylfurfurane (m. p. 96°), and when heated with alcoholic ammonia in a sealed tube diphenyl-α-naphthylpyrrol (m. p. 122°) is formed. Desyl-β-naphthone melts at 155°. When benzaldehyde was heated to 150° with powdered potassium cyanide a good yield of benzoin was obtained. Desylacetophenone and desyl-α-acetonaphthone were easily prepared by condensing by means of powdered potassium cyanide or potassium hydroxide. The yield of desylacetomesitone (m. p. 115°) was 61 per cent. of the theoretical, when benzoin and acetomesitone were heated at 150° with potassium hydroxide. Diphenylmesitylfurfurane (m. p. 87°) and diphenylmesitylpyrrol (m. p. 188°) were prepared by the usual reactions from desylacetomesitone. When a fused mixture of benzyl cyanide and benzoin were heated with potassium cyanide there were obtained, in addition to the reaction-product formed when alcoholic solutions were used, benzalbenzyl cyanide, diphenylsuccinic nitrile, and a yellow amorphous substance, which was not investigated.

Camphoric Acid. By William A. Noyes. *Am. Chem. J.*, **22**, 256–266.—The author shows that facts established by himself and by others indicate that the formula of camphoric acid proposed by Perkin (*Proc. Chem. Soc.*, 1896, 191) and by Bouveault, which represents the compound as a derivative of succinic acid, is probably correct. The results of a study of the ketone $C_8H_{14}O$, prepared by Noyes and Harris (*this Rev.*, **3**, 12), give further evidence of the correctness of this view. The synthesis of this ketone from isoamyl bromide was attempted but has not been completed. Amyl bromide, from the amyl alcohol

of fusel oil, was converted into isocaproic acid, which was oxidized to isocaprolactone. From this compound was prepared γ-bromisocaproic ester, which yielded with sodium ethylate and cyanacetic acid a small amount of dimethylcyancarboxethylcyclopentanone, an unsaturated fatty acid being formed at the same time. This ketone melts at 148.5°, and when heated in a sealed tube with water at 150°–160° loses the cyanogen group. (With J. W. SHEPHERD.) Dihydrociscampholytic acid was converted into the chloride of the α-brom acid by treatment with phosphorus pentachloride and bromine. The ethyl ester, prepared from the chloride, was shaken with a solution of barium hydroxide. The hydroxy acid (m. p. 112°) so prepared was converted into the ketone $C_8H_{14}O$, mentioned above, by distillation with lead peroxide and sulphuric acid. The ketone boils at 167°–169° and forms an oxime which melts at 104°. It, in all probability, is a cyclopentanone, and has the formula



for it condenses with but one molecule of benzoic aldehyde to form the compound $C_8H_{12}O{=}CHC_6H_5$ (m. p. 74°).

Researches on Substitution: The Action of Bromine on Metachlor-, Metabrom-, and Metaiodoanilines. BY H. L. WHEELER AND WILLIAM VALENTINE. *Am. Chem. J.*, **22**, 266–280.—When *m*-bromaniline, dissolved in glacial acetic acid, was treated with an equal molecular quantity of bromine, the product obtained in largest amount was 3,4-dibromaniline; next in amount was 3,4,6-tribromaniline; then followed 2,3,4-tribromaniline and a small quantity of 2,3,4-6-tetrabromaniline. The bromination of *m*-chlor- and *m*-iodoanilines gave similar results. It follows, therefore, when bromine acts upon aniline which contains a halogen atom in the meta position, it substitutes the hydrogen in the order 4, 6, and 2. Previous work has shown that position 6 is the most favored for an entering halogen atom in *m*-nitroaniline. As a result of the work the following substances were prepared: 3-chlor-4-bromaniline (m. p. 67°–68°) and its hydrochloride, sulphate, and picrate; nitrochlorbrombenzene, NO_2ClBr,1,4,3 (m. p. 49°–50°); 3-chlor-4-brom-2,6-dinitraniline (m. p. 169°–170°); 3-chlor-4-bromacetanilide (m. p. 125°); 3-chlor-4-brom-6-nitroacetanilide (m. p. 129°–130°); 3-chlor-4-brom-6-nitraniline (m. p. 202°–203°); 4-chlor-3-bromnitrobenzene (m. p. 60°); 4-chlor-3-bromaniline (m. p. 78°); 3-chlor-4,6-dibromaniline (m. p. 79°–80°); 3-chlor-2,4,6-tribrom-

aniline; 3,4-dibromaniline (m. p. 80°–81°) and its hydrochloride, picrate, and sulphate; 3,4,6-tribromaniline (m. p. 85°-86°); 1,3,4-tribrombenzene (m. p. 44°); 3,4,6-tribromacetanilide (m. p. 188°–189°); 3,6-dibromacetanilide (m. p. 171°–172°); 3-iod-4-bromaniline (m. p. 77°) and its hydrochloride, sulphate, and picrate; 3-iod-4-acetanilide (m. p. 138°–139°); 3-iod-4,6-dibromaniline (m. p. 81°); 3-iod-2,4,6-tribromaniline (m. p. 115°–116°).

Upon the Action of Diazo Compounds on Thymolparasulpho Acid. By James H. Stebbins, Jr. *J. Am. Chem. Soc.*, **21**, 741–746.—By the action of diazonaphthionic acid on *p*-thymolsulphonic acid, a substance which had a crimson-red color and an azo compound were formed. The latter compound was isolated in the form of its barium salt, which probably has the formula $baSO_3.C_{10}H_6N{=}NC_{10}H_{12}O.SO_3ba$.

Halides and Perhalides of the Picolines. By Paul Murrill. *J. Am. Chem. Soc.*, **21**, 828–854.—A large number of salts were prepared which resemble closely in composition and properties analogous compounds of this class.

An Electrolytic Study of Benzoin and Benzil. By Joseph H. James. *J. Am. Chem. Soc.*, **21**, 889–911.—The electrolytic oxidation of benzoin in sodium hydroxide solution yielded benzoic acid and tarry decomposition-products. In sulphuric acid the same result was obtained, but in the presence of hydrochloric acid benzil was also formed. The electrolytic reduction of benzoin gave a body, the nature of which was not established, but which differed from the compounds formed by the reduction of benzoin by sodium amalgam or zinc and hydrochloric acid. The electrolytic oxidation of benzil gave benzoic acid when the solvent was sulphuric acid. In other cases either no oxidation took place or tarry products were formed. The electrolytic reduction of benzil in sodium hydroxide solution gave nothing definite, but in sulphuric acid a good yield of almost pure benzoin was obtained. From the above it is seen that electrolytic oxidation and reduction give practically the same result as those obtained by chemical means, but not so readily or with as good yield.

The Chromic Acid Test for Cocaine. By George L. Schaefer. *J. Am. Chem. Soc.*, **21**, 936–938.—The author replies to criticisms of the test proposed by him and gives further directions for its use.

The Action of Sodium Methylate upon Dibromides of Propenyl Compounds and of Unsaturated Ketones. By F. J. Pond, O. P. Maxwell, and G. M. Norman. *J. Am. Chem.*

Soc., **21**, 955–967.—In a former paper (*this Rev.*, **4**, 9) it was shown that certain ethers which contain a propenyl group readily form dibromides, which are converted into ketones on treatment with sodium methylate. It is shown in the present paper that isoapiol and propyl isoeugenol undergo similar transformations and that dibromides of certain unsaturated ketones of the formula $R—CH=CH—CO—C_6H_5$ may be readily changed into 1,3-diketones.

The Electrolytic Oxidation of Succinic Acid. By CHARLES H. CLARKE AND EDGAR F. SMITH. *J. Am. Chem. Soc.*, **21**, 967–972.—When a solution of succinic acid in sodium hydroxide or alcohol was subjected to the action of electrolytic oxygen the following substances were formed: tartaric acid, oxalic acid, oxygen, carbon monoxide, carbon dioxide, ethylene, methane, and some aromatic bodies which were not studied.

On β-Heptylamine. By THOMAS CLARKE. *J. Am. Chem. Soc.*, **21**, 1027–1032.—β-heptylamine was prepared by heating β-heptyl bromide with ammonia in a sealed tube. Heptylene was produced as a secondary product. The hydrobromide, hydrochloride, oxalate, and double salts of the amine with platinic and auric chlorides are described.

Hydrogen Peroxide as a Test for Salicylic Acid. By W. E. RIDENOUR. *Am. J. Pharm.*, **71**, 414–416.—A dilute solution of sodium salicylate gives a cherry-red color when treated with hydrogen peroxide in the presence of an ammoniacal solution of ammonium carbonate. One part of acid in 2,000 parts of water can be detected in this way. The conditions necessary for the reaction and a table showing the influence of a large number of chemicals are given.

Acet-*p*-sulphanilate of Sodium. By GEO. W. FUNCK. *Pharm. Rev.*, **17**, 249–254.—The author gives a review of all the work done on the above compound. This includes a complete bibliography of the salt and an account of its history, formation, preparation, and physical, chemical, and therapeutic properties.

Acetanilide. By CHARLES W. GORR. *Pharm. Rev.*, **17**, 295–305.—This article consists mainly of a résumé of the present knowledge concerning the modes of formation and of preparation, and the chemical and physical properties of acetanilide.

GEOLOGICAL AND MINERALOGICAL CHEMISTRY.

M. L. FULLER, REVIEWER.

Analysis and Composition [of Roscoelite]. By W. F. HILLEBRAND. *Am. J. Sci.*, **157**, 451–454.—Samples of this

vanadium mica from Eldorado County, California, were analyzed by the author with a view of reconciling the discrepancies between the analyses of Roscoe and Genth, and of establishing a satisfactory formula. A detailed description of the methods used in the determination of vanadium is given. The analyses varied from those of Roscoe in that no manganese or calcium was found, and from those of Genth in having over three per cent. more V_2O_3.

Chemical Constitution of Roscoelite. By F. W. Clarke. *Am. J. Sci.*, **157**, 454–455.—From the analysis of Hillebrand the author has calculated the empirical formula to be

$$H_{468}K_{220}Fe_{22}Mg_{41}Al_{228}V_{216}Si_{768}O_{2724}.$$

Considering the groups SiO_4 and Si_2O_6 to be replaceable, the formula reduces to $R'_{676}R''_{69}Al_{220}V_{216}(SiO_4)_{536}(Si_2O_6)_{71}$, which would indicate, according to Clarke's mica theory, a mixture of three molecules, representing respectively a normal phlogopite, a trisilicate alkaline biotite, and a vanadium muscovite, the last forming 74.5 per cent. of the whole mass.

On the Chemical Composition of Parisite and a New Occurrence of it in Ravalli County, Montana. By S. L. Penfield and C. H. Warren. *Am. J. Sci.*, **158**, 21–24.—The parisite occurs in a fine-grained, friable white substance resembling decomposed rhyolite or trachyte, and is associated with numerous pyritohedrons of pyrite. It crystallizes in rather long hexagonal shafts, made up of pyramids in oscillatory combination, and terminated by distinct, somewhat enlarged pyramids. A study of the analysis made by the authors indicates that parisite is probably a double carbonate of the formula $2(RF)CO_3.CaCO_3$ or $(RF)_2Ca(CO_3)_3$, in which R=Ce, La, Di, etc.

The Constitution of Tourmaline. By F. W. Clarke. *Am. J Sci.*, **158**, 111–121.—Upon reducing to a common basis of six silicon atoms, the formula $H_{11}Al_3B_3Si_6O_{31}$ of Penfield and Foote becomes $H_{16.5}Al_{4.5}B_3Si_6O_{31.5}$, while that of Clarke is $H_{14}Al_5B_3Si_6O_{31}$. The author holds the view that these slight differences amount to no more than the uncertainties of the analyses, and in support of this view gives a series of formulæ computed from Rigg's data, which show variations beyond both extremes, and make it probable that neither formula can be accepted without qualification as final. The intimate relation of tourmaline to mica is indicated by the alteration of the former to mica, by the parallelism in composition between the two when they occur together, and by the similarity in the commingling of isomorphous molecules in the two groups. Allied to muscovite, $Al_3(SiO_4)KH_2$, is $Al_3(SiO_4)_6(BO_3)_3.BO_3H_3.H_{12}$, the tour-

maline acid, in which the H may be replaced by Ca, Mg, Na, and Al. Numerous examples of mixtures of isomorphous molecules of this tourmaline acid are given. The formulæ advanced by the author as covering all established variations in composition and rendering intelligible the various isomorphous mixtures, are as follows:

$$\begin{array}{l} \quad\;\; SiO_4{\equiv}R'_3 \\ Al{-}SiO_4{\equiv}Al \\ \quad\;\; SiO_4{=}AlBO_3 \\ \quad\;\; \vert \\ \quad\;\; Al{-}BO_3{=}R'_3(R'') \\ \quad\;\; \vert \\ \quad\;\; SiO_4{=}AlBO_3 \\ Al{-}SiO_4{\equiv}Al \\ \quad\;\; SiO_4{\equiv}Al(R'_3) \end{array} \qquad \begin{array}{l} \quad\;\; SiO_4{\equiv}R''H \\ Al{-}SiO_4{\equiv}R''H \\ \quad\;\; SiO_4{=}AlBO_3 \\ \quad\;\; \vert \\ \quad\;\; Al{-}BO_3{=}R'' \\ \quad\;\; \vert \\ \quad\;\; SiO_4{=}AlBO_3 \\ Al{-}SiO_4{\equiv}R''H \\ \quad\;\; SiO_4{\equiv}R''H \end{array}$$

The objection to these formulæ, and also to that of Penfield and Foote as well, is that the end products contain no alkalies, while in reality an alkali-free tourmaline is unknown. Assuming these formulæ, the variations from the supposed ratio of silicon and boron of 2 : 1 are accounted for by the supposition that part of the bivalent group of atoms $=Al{-}BO_3$ is replaced by the similar groups $=Al{-}OH$ and $=Al{-}F$. Room for alternatives still exists, and future investigation may prove a derivation from a complex boro-silicic acid as yet unknown.

Note on a New Meteoric Iron Found near Tombigbee River, in Choctaw and Sumter Counties, Alabama, U. S. A. By Warren M. Foote. *Am. J. Sci.*, **158**, 153–156.—Detailed descriptions are given of the appearance, structure, and occurrence of six masses with an aggregate weight of nearly a hundred pounds. An analysis made by Mr. J. E. Whitfield showed 95 per cent. iron, 4 per cent. nickel, with small amounts of cobalt, phosphorus, carbon, and sulphur.

An Albertite-like Asphalt in the Choctaw Nation, Indian Territory. By Joseph A. Taff. *Am. J. Sci.*, **158**, 219–224.—This asphalt, which is found in several localities in the vicinity of McAllister, in the southeastern portion of the territory, occurs as stringers in veins filling fissures along zones of thrust faulting in shales of unknown age. Although an analysis showed that in composition it was very similar to certain bituminous coals of the same region, its brittleness, easy fusibility, and more especially its distillation products, show that it should be placed among the asphalts. Of these it most nearly resem-

bles albertite, the only important variation being the greater solubility of the latter in terpentine.

On the Separation of Alumina from Molten Magmas, and the Formation of Corundum. By J. H. PRATT. *Am. J. Sci.*, **158**, 227–231.—The evidences bearing upon the separation of alumina from molten magmas as presented in the field by the various types of peridotites of North Carolina are discussed, and an account given of the experiments of Morozewicz and their results. The conclusions are as follows: (1) Corundum will not separate out from a calcium-sodium-potassium silicate magma unless the ratio of alumina to the other bases is more than 1 : 1 and that of silica is less than 6. (2) It will not separate unless more than enough alumina is present to unite with all the magnesia and iron in the magma. (3) All alumina in a magnesium silicate magma, if there is no excess of magnesia, will separate as corundum. (4) If magnesia is in excess, the excess will unite with alumina to form spinel, the remainder separating as corundum. (5) In the presence of chromic oxide in a magnesium silicate magma, slight amounts of alumina and magnesia unite with the chromic oxide to form chromite, but corundum and spinel do not separate. (6) In peridotite magmas containing alkalies or alkali earths a portion of the alumina unites with them to form feldspar. (7) The tendency of alumina to unite with alkalies or alkali earths to form double silicates is strong, but it has little tendency to unite with magnesia when the magma is a magnesium silicate.

Experiments Relative to the Constitution of Pectolite, Pyrophyllite, Calamine and Analcite. By F. W. CLARKE AND GEORGE STEIGER. *Am. J. Sci.*, **158**, 245–257.—The purpose of the examination was to gain evidence of the chemical structure of silicates by means of fractional analyses. 1. Pectolite. The radiated variety from Bergen Hill, N. J., was analyzed, the analysis giving the accepted formula $HNaCa_2Si_3O_9$. To determine whether this represents a true metasilicate, the mineral was ignited and afterwards boiled in a solution of sodium carbonate, with the result that a mean of 8.68 per cent. of silica (the amount proportional to the acid hydrogen) went into solution. Boiling the unignited mineral in the sodium carbonate solution, or even with water alone, resulted in a slow decomposition with loss of both silica and bases. The loss on boiling for 16 hours in distilled water was 4.09 per cent. 2. Pyrophyllite. On strongly igniting and treating with a solution of sodium carbonate, it was found that only 2.84 per cent. of silica was liberated, indicating that the mineral may with propriety be regarded as a basic salt of the acid $H_2Si_2O_5$ with the formula Si_2O_5= Al—OH. Pyrophyllite was only slightly attacked by heating

with dry ammonium chloride. 3. Calamine. On igniting no definite fraction of water was split off. Boiling with sodium carbonate dissolved slight amounts of silica and zinc, but no breaking up into definite distinguishable fractions occurred. The evidence, though negative, is in favor of the usual formula $SiO_2=(ZnOH)_2$. 4. Analcite. On ignition and treatment with sodium carbonate solution only a slight amount of silica was split off, indicating the absence of metasilicic acid or an acid metasilicate. On heating with dry ammonium chloride there was again very little silica split off, but half of the sodium was converted to NaCl, and part of the water replaced by NH_3, giving a residue of $H_2Na_2Al_4Si_8O_{24}.NH_3$. This points to the original formula of $Na_4Al_4Si_9O_{24}.4H_2O$, which is contrasted with the usual formula $NaAlSi_2O_6.H_2O$. The conclusion from the probable structural formula is that analcite is a member of the garnet-sodalite group.

The Mineralogical Structure and Chemical Composition of the Trap of Rocky Hill, N. J. By ALEXANDER HAMILTON PHILLIPS. *Am. J. Sci.*, **158**, 267–285.—Numerous analyses of the trap and of several of the component minerals are given. The trap occurs in the form of a dike and in general appearance resembles a dolerite. In composition, however, it approaches closely to diorite but with border phases allied to diabase.

Some Analyses of Italian Volcanic Rocks. I. By HENRY S. WASHINGTON. *Am. J. Sci.*, **158**, 286–294.—The analyses of the trachytes of the Phlegraean Fields and Ischia indicate that these volcanic rocks are not genetically related to the closely adjacent rocks of Somma and Vesuvius, but are connected with a second and older fracture line extending from Capraia to Sicily, and covered largely by the waters of the Mediterranean. The rocks of this latter fracture show an excess of Na_2O over K_2O, while in the former K_2O and CaO predominate. A third fracture line, the oldest of the three, occurs far out in the Mediterranean and is characterized by rocks very high in Na_2O and possessing several peculiar sodium minerals.

Mineralogical Notes: Melonite, Coloradoite, Petzite, Hessite. By W. F. HILLEBRAND. *Am. J. Sci.*, **158**, 295–298.—An analysis of a nickel telluride from the Mother Lode region of California gave the formula $NiTe_2$, and is regarded by the author as probably identical with the melonite (Ni_2Te_3) of Genth, which was obtained from the same locality. Other minerals recognized from this locality were coloradoite, petzite, and hessite. Analyses are given for the last two.

An Account of the Character and Distribution of Maryland Building Stones. By EDWARD B. MATHEWS. *Maryland Geol. Surv.*, **2**, 125–241 (1898).—An extended description, accompanied by colored plates, is given of the common building stones, including granite, gneiss, limestone, marble, sandstone, and slate. The descriptions of the more typical varieties are supplemented by analyses.

The Physical, Chemical, and Economic Properties of Building Stones. By GEORGE P. MERRILL. *Maryland Geol. Surv.*, **2**, 47–123 (1898).—A general description of the building stones of Maryland is given, supplemented by a discussion of the weathering agencies, both chemical and mechanical, and their effects upon the color, strength, and durability of the various stones. The chemical tests used to determine the permanence of color and resistance to corrosion, together with the mechanical tests for determining the absorptive powers, resistance to freezing, resistance to abrasion, crushing strength, etc., are described at some length.

Summary Report of the Geological Survey Department for the Year 1896. By G. M. DAWSON. *Geol. Surv. Canada, Ann. Rep.*, **9**, *Rep. A*, 3–144 (1898).—In addition to the accounts of the geological work, the report includes a general description of the work done in the chemical laboratory of the survey upon the waters, fuels, building stones, ores, etc., of Canada.

Report of the Section of Chemistry and Mineralogy. By G. CHRISTIAN HOFFMAN. *Geol. Surv. Canada, Ann. Rep.*, **9**, *Rep. R*, 1–53 (1898).—The report includes a large number of analyses of coals, building stones, waters, and minerals, by F. G. Wait and R. A. A. Johnston. Of the minerals, the most noteworthy is that of baddeckite, a new copper-red variety of muscovite, corresponding to the formula

$$H_4(CaMgK_2Na_2)(Fe_2Al_2)_3Si_6O_{22}.$$

The results of some 87 gold and silver assays, and 5 nickel and cobalt assays by Mr. Johnston are also given.

APPARATUS.

A. H. GILL, REVIEWER.

An Apparatus to Facilitate Hydrogen Sulphide Precipitations. By R. K. MEADE. *J. Am. Chem. Soc.*, **21**, 421.—The gas enters and exits through openings of capillary size, and the absorption is aided by shaking.

A Simple Volumenometer. By C. E. Linebarger. *J. Am. Chem. Soc.*, **21**, 435–437.—The apparatus resembles that of McKenna and possesses the additional advantage that it can be constructed of apparatus occurring in any laboratory.

The Incandescent Lamp as a Source of Heat in Ether Extraction. By C. G. Hopkins. *J. Am. Chem. Soc.*, **21**, 645–647.—Five 32-candle-power lamps furnish sufficient heat for twenty sets of Soxhlet extractors.

An Electric Drying Oven. By T. W. Richards. *Am. Chem. J.*, **22**, 45–49.—The oven itself consists of one large bottomless beaker inside another, both resting upon a tile, which is supported upon layers of asbestos and wire gauze. An inverted clock glass or porcelain dish serves as a cover. The source of heat is 5 m. of platinum wire, 0.2 mm. in diameter, wound upon a reel of glass rods and porcelain bars; a current of 2 amperes (potential of 52 volts) gives heat sufficient to heat the oven 140° above the temperature of the room. To equalize the temperature within the oven a face is placed immediately above the heating coil. The apparatus is safe, easily constructed, and very satisfactory.

A Serviceable Generator for Hydrogen Sulphide. By W. P. Bradley. *Am. Chem. J.*, **21**, 371–376.—The apparatus, which cannot well be understood without the figure, is easily constructed and cared for, and after an experience of nine years is said to leave little to be desired.

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